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(Geomorphological, Geological And Topographical Description Of Uruguay)

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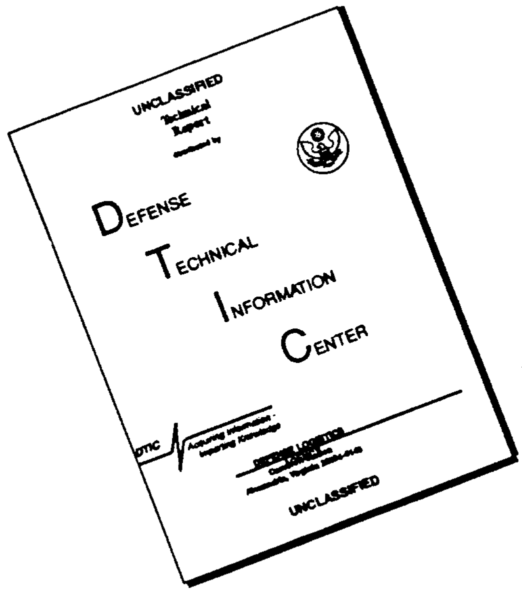

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ECONOMIC AND GEOGRAPHIC TRANSLATIONS ON LATIN AMERICA

No. 32

GEOMORPHOLOGICAL, GEOLOGICAL AND TOPOGRAPHICAL DESCRIPTION OF URUGUAY

[Following is a translation of Chapters II, III and IV of a monograph by Jorge Chebataroff entitled Tierra Uruguaya (The Land of Uruguay), An Introduction to the Physical, Biological, and Human Geography of Uruguay, Montevideo, 1960, pp 51-132.]

CHAPTER II

Location, Size and General Geomorphological Features

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Location. -- The present territory of the Eastern Republic of Uruguay is located on the southeastern part of the South American continent with an extensive coast along the Rio de la Plata (River Plate), and to a lesser degree, along the Atlantic Ocean. It borders in the north and northeast on Brazil and in the west on Argentina, from which it is separated by the Uruguay river and the estuary of the Plate. Next to Chile and Argentina, which extend considerably in latitude, it is the southernmost country in South America. It is contained approximately between the 30th and 35th parallels latitude South and the 53rd and 58th meridians longitude West (in relation to Greenwich); it is situated entirely within the Temperate Austral Zone.

The extremities of the territory are Punta del Este in the South, which is located at 34°58' latitude South in the ocean, and in the north a curve in the river Cuareim in the zone of the Canelera and Charrua straits located at 30°06' latitude South; in the east, and on Laguna Merin, the extremity is Point Muniz at 53°11' longitude West, and on the opposite side the extremity is located in the department of Soriano, in a projection situated to the south of the mouth of the

Arenal Grande stream on the Uruguay River, at $58^{o}26'$ longitude West. Punta del Este is the continental southern extremity but Lobos Island, in relation to it, has a more southerly position. The port of Montevideo is located at some $34^{o}54'$ latitude South and $56^{o}12'$ longitude West (in relation to Greenwich.

Taking into account the present international boundaries, the territory of Uruguay, on the whole, offers a relatively rounded outline, or better yet, pentagonal.

Size. -- It is still quite difficult to make an exact estimate of the area of the territory of Uruguay. Although the official figure for the surface area of the country is 186,926 sq km, there are many estimates which differ appreciably from this figure. At any rate, we are relatively sure that the exact figure is not very different from the one which is commonly accepted.

> Among the estimates and calculations which have been made with respect to our national territory, we will present the following: that of J.M. Reyes, who attributes a surface area of 217,000 km^2 to the country; that of Alberto A. Marquez, who reduced this figure to 178,000 km^2; and that of Francisco J. Ros, who arrived at the intermediate figure of 205,618 km^2. An estimate of the area of the country would seemingly fall somewhere between 180,000 and 190,000 km^2, but would approach more closely the former figure than the latter. Although the most accurate estimate seems to be 181,000 km^2, we will use the current and rounded-off figure of 187,000 km^2.

In terms of its area, Uruguay is the smallest country in South America, but it is larger than any one of the countries which comprise Central America. It is more extensive in area than each of the following European nations: Albania, Andorra, Austria, Belgium, Bulgaria, Czechoslovakia, Denmark, Greece, Ireland, Liechtenstein, Luxembourg, Monaco, The Netherlands (Holland), Portugal (Uruguay is twice as large as this country), San Marino, The Vatican City, Switzerland, and Hungary. Belgium wouldfit into the area of Uruguay six times.

We will not dwell upon an abundance of area comparisons with other countries; this is a favorite habit of some writers, but frequently it is senseless. If we assume that the territorial limit is a sufficiently big disadvantage, then it is impossible, for example, to compare Uruguay with a portion of the Arabian Desert or with the mountainous and high-altitude Tibet. On the other hand, the area alone of a country cannot account for its prosperity; there are extensive areas which are poor, and there are relatively small areas which have achieved an enviable economic level. It is also impossible for us to compare our country with Belgium, since the economy of the latter is backed up by the natural resources of the Congo, which is 80 times its size. All we should keep in mind is that the area of Uruguay is 45 times less than that of Brazil, and 15 times less than that of Argentina.

As a result of successive boundary treaties the area of the old Banda Oriental (Eastern Band) fluctuated and was reduced almost constantly. At the completion of the Preliminary Peace Conference of 1828, Uruguay had an area slightly greater than it has today. The treaty, or treaties, of 1851 deprived her of what was called the Rincon de Artigas (Artigas' Corner) or the Cuareim and the area which includes the headwaters of the Negro River. However, in the Treaty of 1909, favorable adjustments were made for our country with regard to the sovereignty of the waters of a portion of Laguna Merin (Merin Lake) and of the Yaguaron River.

There were also some changes with respect to the possession of the Martin Garcia Island, which today belongs to Argentina, and with several islands along the Uruguay River. We will discuss these further at a later time when we study the international limits.

Advantages derived from the geographic location.- Uruguay, as we said before, has an Atlantic Ocean coastline, and it is also situated at the entrance of an immense network of navigable rivers which comprise the River Plate estuary, the Uruguay River, and the Parana River with all its tributaries (The Paraguay River, for example) and its sub-tributaries, the Pilcomayo River, for example, which is a tributary of the Paraguay River). This network made possible an early exploration of the lands to which it supplies water; we should think back upon the voyages of Gaboto, Diego Garcia, and others. Presently, the rivers which compose this network, and above all the Parana, the Paraguay and even the Uruguay River, are a vital factor in the economy and the commercial and cultural relations between Argentina, Paraguay, and to a lesser degree, between our country and Brazil. With regard to climate, the advantages derived from the geographic location are relative, since on an average, our climate is temperate and the differences among the seasons are not strongly marked. The lack of orographic barriers and other factors frequently cause fluctuations in the weather, and in a rapid and practically unforseeable fashion.

On the other hand, Uruguay is characterized by a gently rolling relief or it is completely flat; it has a dense hydrographical network even though it cannot be easily utilized for navigation; seismic tremors of marked intensity, which are so terribly feared in the Andean countries, are unheard of here; furthermore, there are no active volcanoes. With regard to the supposed relative advantage of the rich soil, we will discover later on that this is more apparent than real, although there is an abundance of natural pastures which provide valuable forage.

Having an coastline with several relatively deep harbors on the River Plate estuary and numerous sandy beaches with considerable tourist value constitutes an undeniable advantage which Uruguay, until now, has taken advantage of to a moderate degree. For example, the Atlantic coast, until now, has been utilized very little; furthermore, it has no real port, since La Paloma cannot efficiently fulfill that condition.

With respect to the subsoil, Uruguay is characterized by a lack of metal ore and combustible minerals even

though it has an abundance of a variety of rocks, including marble, argil, ochre, mica, dolomite, calcite, slate, etc. Among precious metals, there is coal, which was once mined, but its extraction did not prove to be very profitable.

> Explorations to find petroleum, until now, have not provided any positive results; there are deposits of peat and thin layers of economically unexploitable coal. Certain deposits of iron ore and manganese seem to be important, but they are located at great distances from the population centers and the ports. The lumber forests are not very extensive, so wood must be imported from foreign countries.

Uruguay, in spite of its advantageous location with regard to navigable rivers and the ocean, and having an agreeable climate and a rich layer of natural pastureland, has certain unfavorable aspects which in some cases have been overcome, and in others they have not. At any rate, well-directed human activity has made possible more achievements in this only moderately endowed land than that which has been carried out in more favorable areas.

General physical aspect of the country. -- Uruguay rests upon the southernmost part of the gigantic crystalline shielding called Brasilia by the geologists. The component rocks of the latter crop out principally in the southern part of the country, disappearing in the north, and in a good part of the periphery of the country underneath sedimentary layers or a volcanic layer of basic effusive rocks. The rocks of the crystalline shield, subject to various movements and affected by erosive cycles of long duration, have been reduced until a softly rolling surface was produced which pertains to a peneplain. It appears in some of the mountainous zones and the seas of stone without presenting a marked continuity. Relatively recent sediments have been deposited along the left of the Plate coast and around Laguna Merin. Until today they have been relatively undisturbed and constitute true coastal plains. On the other hand, sediments and volcanic layers which dominate the northern part of the country and are older than these deposits of the plains to which we just referred, have been arched or inclined, at times dislocated, and later were subjected to large cycles of erosion. They ultimately led to the formation of a peneplain with more level shapes than those which characterize that of the crystalline rocks of Brasilia.

There are at least three different types of geographical landscapes in our country: the peneplain, with both its crystalline and sedimentary portions; which do not have any rolling hills of importance and are at an elevation only slightly above sea level; and the mountains, which are situated primarily in the eastern portion of the departments of Maldonado and Lavalleja. However, a more thorough examination points out a fourth type of landscape which pertains to the rolling surface of the basaltic strata in the northeast; it bends gently towards the Uruguay River and on the other side it is characterized by an irregular but quite prominent scarp; it consists of a gigantic hill of volcanic materials superimposed upon sandstone which dips downward towards the west.

The peneplains, the basaltic hill, and the mountains, have been affected principally by the river pattern, which as we later will discover, has undergone some relatively recent light rejuvenations, which have been considered along with other such epirogenic movements. This river pattern has created elongated and ramified undulations with broad hillsides and gentle slopes which are called <u>cuchillas</u> (mountain ridges). These cuchillas are generally gently rounded in the crystalline part of the peneplain; on the other hand, they are more level in the sedimentary part. They all take part in the important hydrographical function of distributing rainwater to opposite river valleys; this helps to explain the name cuchillas.

This relief of peneplains with undulations in the form of cuchillas, mountains, and scarps of ridges is located in the southern part of the Brazilian state Rio Grande do Sul, the terrain of which, aside from the geomorphological factors, shares many common features with that of Uruguay; examples are the presence of prairies primarily in the southeastern part of the country and the coastal surfaces which border on the ocean and wind around the coastal lakes in the eastern part. There is also a certain similarity between the cuchillas of the relief of Uruguay and what is called the Argentine Mesopotamia, which is contained between the Parana and Uruguay Rivers.

In turn, the differences are considerable if we compare Uruguay with the Pampa. The relief of the former is undulated with cuchillas; they are absent or slightly noticeable in the latter. In Uruguay strong rocks and old sediments crop out everywhere, the hydrography is dense, and the graminous vegetation intermingles with

various shrubs and bushes, the rivers appear to be bounded by border brush (terraced woods). In the Pampa, the Pampa mud flat predominates (recent sediment), the hydrographic network is poorly organized, and the basically graminoid plant steppe grassland extends everywhere. There are closer relations from a physical standpoint between the Uruguay and the neighboring counties of the Argentinian Mesopotamia and Rio Grande do Sul than with the former and the Pampa.

> The characteristics of the Pampa have too frequently been attributed to Uruguay, especially by European authors. Perhaps the only resemblance between these two territories is based on the peculiarities of the climate, and even so, the Pampa climate in general is drier than that of Uruguay. The difference in the landscape is at least significant enough for the idea to find a similarity between both regions to be abandoned completely, except when the so-called Pampa Sierras are involved (the Tandil mountain chains, the southernmost portion of the Cordoba mountains, etc.) which on the other hand, rather than real components of the Pampa, form a profound contrast with it, emerging like islands from an enormous plain, which is both sedimentary and graminous.

We will see later that the similarity which exists between Uruguay, the southern portion of the state of Rio Grande do Sul, and to a certain extent the Argentinian Mesopotamia, from the geomorphological viewpoint, extends to other facets, such as vegetation, soil, climate, etc., and between Uruguay and the southern part of Rio Grande, may also be established between the respective geological constitutions which do not respect political borders and the presence of mountain chains and seas of stone. Regarding the geological structure, the similarities between Uruguay and Rio Grande do Sul are so pronounced that the discovery of any geological fact in either one of them calls attention immediately to the other, because it may occur that the manifestation of this fact is also peculiar to the territory of the other; therefore terminology imported from Southern Brazil has been used in Uruguay where research with respect to the structure and chronology of the Gondwana was started first.

The statement that Uruguay, from the physiographic and geological viewpoint is an appendix of Brazil is perhaps somewhat exaggerated, because there exist characteristic terrains, not yet indicated in Rio Grande do Sul (for example, the Capas de Fray Bentos, so abundant in the west of our country and in the Argentinian Mesopotamia). However, in general, it cannot be denied that the analogies are so frequent that they justify this expression at least in part.

From the viewpoint of vegetation, the analogies of the three territories indicated above led the phytogeographers and botanists (Grisebach, Hauman, A. Castellanos, etc.) to consider the existence of a Uruguayan Province of Vegetation, which would extend throughout Uruguay, the Argentinian Mesopotamia (except for Misiones) and the southern portion of the State of Rio Grande do Sul. Throughout this area a prairie predominates where together with the graminous layers various bushes intermingle, where larger bushes and growth appear in the vicinity of the streams and rivers, in the stone quarries and seas of stone, and on the slopes of the mountains and ridges.

From a general viewpoint only, Uruguay and the the part of Rio Grande do Sul located south of the Central Depression of that state form a single physiographic unit and a single geological section. The Argentinian Mesopotamia, without completely sharing the physical characteristics of Uruguay approaches it in many aspects (the relief of cuchillas, vegetation and climate). Regarding the intent to identify Uruguay and Pampa, they are as illusory as those which tried to relate it to the Chaco or the Southern Plateau of Brazil.

We must point here that no serious Argentinian author of treaties has been in favor of this assimilation; in turn, foreign writers did so who were unfamiliar with the country of the River Plate.

Expressions such as the countries of the River Plate or the River Plate republics have served to give greater substance to the ideas that territories characterized by a certain uniformity or which have sufficient similarity

to be included under a single name are involved. These expressions only refer to the fact that the River Plate is something like the entrance door to these countries or a window opened to the outside world, where the capitals are located and where the commercial activities of the River Plate countries are concentrated; on the other hand, the River Plate estuary, as we said before, opens a road to the interior of the continent, through which colonization has advanced, although it also had as its original and relatively stable focus the city of Asuncion, which on the other hand is located on the Paraguay River, a tributary of the Parana, the latter being one of the major rivers contributing to the River Plate.

Furthermore, there is a certain community relationship with respect to the historic and cultural background; the Eastern Band (in part present-day Uruguay) was subject at first to the River Plate Government, established at Buenos Aires, and then to the Vice royalty of the River Plate, which also was established in that city, although the area administered was very extensive and of a greatly varied physiognomy. Later on it was one of the United Provinces of the River Plate.

> Expressions such as the River Plate region, River Plate vegetation, etc., which refer to physical and biological aspects in these territories, have less meaning than others such as River Plate people or River Plate commerce. However, the expression River Plate basin has primarily a clear meaning since the river network converges in these regions largely toward the River Plate.

After crossing the Central Rio Grande do Sul Depression, in the northern direction, the landscape experiences a highly accentuated evolution. The vegetation also changes as well as the climate and other physical characteristics. Changes of equal magnitude are noted when we cross the River Plate, leaving Uruguay for the province of Buenos Aires, or when we pass west of the Parana River after crossing the Argentinian Mesopotamia. The area thus outlined is characterized by no absolute uniformity, since we can easily discover different geomorphological units, climatic changes, vegetation changes, etc. However, this fact does not deny that the entire region has certain physiographic and biogeographic characteristics which differ from those of the surrounding regions (for example the Southern

Plateau of Brazil, Misiones, Chaco, and Pampa), as was perfectly recognized by many researchers in the fields of geomorphology, phytogeography, zoogeography, and other specialized branches of the geographic sciences.

The area to which we referred earlier consisting of three different countries, includes an approximate 460,000 km^2.

Geomorphological sectors or units. We said that in Uruguay at least four regions can be recognized due to their geomorphological differences: the peneplains (which include a crystalline sector and another sedimentary sector); the plains or coastal plains; the mountain chains (without real continuity but which are present mostly in the east); and the basaltic cuesta of the northwest, where the resistance of the superficial rock (basalt) has defended the underlying sandstones against the glyptogenic effects, especially of fluvial erosion. The peneplains are characterized by their generally slightly undulated relief, with cuchillas of various types, and frequent revealing forms (monadnocks, in the crystalline sector, and residual tablelands in the sedimentary sector) which constitute ridges, rugged terrain, sierras and seas of stone. The coastal plains only offer a second order relief, and in general are quite level and frequently inundated. The basalt cuesta slowly dips toward the Uruguay River, presenting a slightly flat surface, with undulations produced by the boxing-in of the river valleys, which even look like ravines, particularly toward the east, where the scarp of the ridge appears, at times with a highly abrupt edge, others hardly noticeable, but in general highly sinuous and cut by valleys that have the shape of ravines (for example, the Eden Valley). The mountain chains which include primarily mountains and rough terrain, the latter being more irregular than the former, on the average wind from SSW to NNE, although they describe an arc of large radius of curvature as a whole, with its concavity turned toward the east.

Locally the mountains offer a different orientation from that indicated and there are some that are entirely different with their SSW to NNE direction, which is the case, for example, of the Carape mountain where the departments of Lavalleja and Maldonado, and that of Acegua and Cerro Largo are located.

Although the regionality of the major relief lines is a real fact in Uruguay, it is difficult to draw the limits between the various geomorphological units, without running the risk of obtaining an exaggerated amount of detail and contours of tremendous complexity if we pursue the intention of reaching extensive accuracy. This intent could only be fulfilled if there were geological, geomorphological and topographic detailed maps of the entire country, on a large scale, and if we were familiar in detail with the entire national territory. Even in this direction much has been done, however the road to travel is still long and therefore we will be satisified here with tracing among the geomorphological sectors borders which are only provisional. Furthermore, it should be said that in other South American countries this problem is even more complex.

With respect to the doubt concerning whether Uruguay, being as small as it is, is able to present true geomorphological units of different characteristics, it should be recalled that Switzerland, four and one half times smaller, contains three geomorphological units which are quite different, and Belgium, of even smaller size (eight times smaller than Uruguay) has three different geomorphological sectors. Only in territories of great uniformity, such as the Argentinian Pampa or Amazonia, these units cannot be recognized in small areas. On the other hand, different geomorphological sectors in our country may be appreciated upon crossing the territory in one or another direction. No one in doubt that there exists a substantial difference between the landscape surrounding the city of Minas and that which prevails in the frequently inundated zone of India Muerta, or still the one which may be contemplated in the region with the well-known Tres Cerros de Cunapiru. Lack of knowledge regarding this geomorphological regionality has led to the fact that in geographic education regarding our country and excess of monotony resulted which still prevails up to a point, substituing an explanation of the real landscape which is really heterogeneous with a listing of cuchillas, all of the same color.

K. Walther was the first one to make a clear distinction, consisting particularly of the fact that the shapes which dominate the relief in the north of the country were different from those which characterized the south. He pointed out that in the north the flat shapes are frequent while in the south the rounded and even crested shapes predominate. The same author performed a valuable service in classifying the shapes and tried to relate the morphology with the geological structure.

Later E.S. Giuffra (1935) classified the relief shapes as to what he called topographic zones, basing himself in part on the preceding work of K. Walther and on the map published by E. Terra Arocena and V. Sudriers under the title of Preliminary Orographic Chart. On a schematic map he outlined the topographic zones by designating them and distributing them as follows:

a) Atlantic Plain, toward the east, along the ocean coast and a large part of the Laguna Merin basin.

b) The region of the hills and mountains, including the mountain zones of Maldonado, Lavalleja, Treinta y Tres, Cerro Largo, Rivera and other departments.

c) The River Plate Peneplain, to the south, particularly a large part of the Santa Lucia basin.

d) The Central Undulated Region, extending from south to north through the middle portion of the country, but widening toward the southwest at the southern end.

e) Coastal Peneplain, along the Uruguay River, and penetrating the interior of the country through the valleys of the tributaries of this river.

f) The Tableland of Haedo, extending through the basaltic zone of northwestern Uruguay.

This division fits reality in many respects, but in others it must be corrected, including with respect to the nomenclature used, especially with regard to the use of the expression "altiplano" [tableland, plateau] to designate the basaltic zone, whose average elevation does not exceed 150 meters, and its surface is inclined westward forming a cuesta, with an appreciable scarp toward the east. Furthermore, in the peneplain of the River Plate the veritable accumulation plains predominate over considerable

areas (Arazati, Atlantida, La Floresta, Solis Grande, etc.). Furthermore the term undulated region (which corresponds to a peneplain) and the term region of hills and mountains, which is not continuous, should be objected to.

In 1951, the author of this book submitted a new scheme in which he tried to outline the various geomorphological units, also indicating their essential characteristics. This scheme, which was reproduced in other publications (1953-1954) included the combined area of Uruguay and Rio Grande do Sul, wherefore there exists continuity between the natural regions of one territory with respect to the other, except with respect to the Southern Brazilian Plateau and the Central Rio Grande do Sul Depression, although the latter may be included in what the aforementioned scheme calls the Gondwana Sedimentary Peneplain. In 1958 the geomorphological scheme, somewhat modified with respect to 1951, included for Uruguay the following geomorphological units or sectors:

a) The Sedimentary Peneplain, extending over Devonian and Gondwana terrain, intercalating in it crystalline terrains (River Plate island, Sierra de Acegua); it occupies the northeast of the country.

b) The Crystalline Peneplain, extending over old geological terrains, although in part covered by Pampa mud in certain areas; to the east, the presence of relatively discontinuous mountain chains, could constitute a veritable subregion of the complex.

c) The Plains (or flatlands) of the River Plate and of Laguna Merin, separated one from another, with the latter possessing greater continuity.

d) The Basaltic Cuesta (inclined toward the Uruguay River, where it is partially covered by Cretaceous and post-Cretaceous terrains and with a highly prominent scarp, but very irregular toward the east).

e) The Valley of the Uruguay River, a more geographic than geomorphological entity, since it is difficult to delineat. At any rate it offers some of its own characteristics, not only from the topographic viewpoint but because of its soil, vegetation and human activity.

With respect to the peneplains, it should be recalled that they actually represent a single unit, since they were

produced by post-Cretaceous erosion cycles. However, the influence of the influence of the rocks and of the structures has been decisive in the creation of the types of relief, and thus in the sedimentary peneplain there predominate the flattened shapes, while in the crystalline the rounded and sometimes crested shapes are more typical. Three sectors could be considered in the peneplain of post-Cretaceous origin: the crystalline, the sedimentary and the basaltic (the latter corresponds to the Basaltic Cuesta).

> With respect to the suggestion made by A. Pochintesta to consider the Uruguay River Valley as being part of the peneplains, the difficulty arises from the fact that the terrains where the lower portion (or even the middle portion) of this valley rests are relatively recent (post-Cretaceous: the layers of Fray Bentos, the terrains of the inter-era transgression, the Pampa mud) and occupy an almost horizontal or a horizontal position; the patterning work has not been able to convert them into a true peneplain, at least in the strictest sense. Rather, involved is a plain raised by epirogenic movements which the Uruguay River proper has sculptured. This observation refers only to the middle and final portions of the river. We will return to this point when we deal with the evolution of the relief.

Since the time when some treaty writers believed our relief of cuchillas to be related by way of Central Brazil (Parecis System) to the Cordillera of the Andes, and even wondered about the apparent agreement in orientation between the Tertiary folds and the mature or senile forms of the Brasilia, many years have past. Today we know perfectly well that these relationships are purely imaginary since when the Brasilia crystalline mass was an entire continent (perhaps connected to Africa, India and Australia), the materials which later on would form the Andes Cordillera sedimented out in a vast epicontinental sea.

> The assumed relationship between our systems of cuchillas and the Andes were mentioned by J.M. Reyes, O. Araujo and other authors. At that time geological knowledge regarding our continent, however, was rudimentary.

<u>Principal Forms of Relief</u>. -- If we examine the present morphology of Uruguay we find that the characteristic forms of the various sectors of the peneplain are the cuchillas; although these undulations pertain to highly varied topographic forms, they fulfill an essential hydrographic function which is that of separating the rainwaters and the riverwaters in the direction of opposite basins. This hydrographic function explains the reason for the very number of cuchillas which have been applied to these cuchillas, but by no means suggests that they are crested or greatly significant in the terrain, since they may pertain to an almost level terrain, with sufficient inclination on one side and the other of the water divide as though in order to cause the water to run off in opposite directions. Therefore, in practice, it is difficult to notice the cuchillas whenever the slops are very lightly inclined.

> O. Araujo, in 1892, defined the cuchillas as follows: "cuchilla, slope, peak, plateau, whenever they extend over a considerable area. Continuity of protuberances, except mountain chains... This is an old term, it is current, geographic and official, and it is the only expression with which any considerably extensive protuberance is named in the River Plate and whose slopes descend mildly toward the level land, feeding or producing with the waters they bear rivers, streams, lakes, lagoons or glens. The Spanish geographers who agreed to the border demarcation between the possessions of Spain and Portugal in South America also used it in their descriptions, maps, etc."

> In 1919 K. Walther, referring to the Uruguay relief, wrote the following: "The senile character of the country's surface becomes manifest in the great lack of well-defined longitudinal directions produced by the history of the origin of the rock material which forms the elevations. Thus, the mountain chains reproduced as broad caterpillars on foreign and domestic maps under the name of "cuchillas" represent nothing other than the separation of the water (divortium aquarum) which however is not level between the water streams."

The cuchillas resulted from the sculpturing process our country experienced under the primary influen e of fluvial action. It is possible that beginning with the Cretaceous (Secondary era) Uruguay was not affected by any major movement capable of producing new reliefs, and in turn was peneplained slowly until it acquired its present state of a peneplain (peneplano, according to Davis' expression). This sculpturing process was applied to the entire country with a certain uniformity, but the diversity of the rocks and structures, as well as the intervention of some secondary movements of a tectonic and isostatic nature gave rise to a series of forms in the various sectors of the peneplain, from leveled or rounded cuchillas to mountains, rugged terrain, seas of stone, scarps and ridges. These forms of relief are of a secondary character within the framework of a geomorphological unit which is the peneplain extending over a large part of Uruguay and the southern part of Rio Grande do Sul where three main sectors can be distinguished: a) crystalline peneplain, b) sedimentary peneplain, c) Basaltic Cuesta.

In each one of these sectors the cuchillas pertain to the masses spreading out between the streams of a given category, responsible for the creation of the valleys and the formation of cuchillas. They emerge precisely when the terrain sank due to the fluvial action, i.e., when the corresponding valleys appeared. Thus among each of the streams there always rises the cuchilla, the water divide between the two fluvial basins; it is possible therefore to find second-order cuchillas, such as those which interpose themselves between the tributaries of these rivers, and so forth. Consequently the real landscape appears to be very complex, with a multitude of undulations and it is difficult to determine directly which is the principal cuchilla in the oomplex.

Although in general the cuchillas are elements of a spread-out relief which in general pertains to the rivers that were responsible for their existence, it is almost impossible to represent them on current maps, something which has been done by resorting to simple lines (which would mark only the water divide, but not the mass of the cuchilla) or the spectacular "caterpillars" (according to the expression of K. Walther, already mentioned) which develop on an apparently level terrain which is a grave error, since the principal cuchilla always leads to second-order cuchillas, these in turn yield the third-

order cuchillas, followed by the fourth-order cuchillas, etc. In reality the entire mass of the principal cuchilla includes the entire territory located between two first-order rivers, but it results in lower-order undulations, and the principal water divide can only be distinguished from it on current maps, which is that which is that separates the first-order river basins from the ones we just mentioned.

A clear example of the agreement between the main cuchilla and the first-order rivers in the department of Durazno may be observed, where the Cuchilla Grande de Durazno interposes itself between the Negro and the Yi Rivers; in turn the branches of this cuchilla interpose themselves between the tributaries of both rivers, and continuing the analysis in this fashion, we would see that the cuchillas of a lower order interpose themselves between the tributaries of the affluence of the Negro and Yi Rivers. These relationships are very significant and show clearly that the cuchillas rose not by rising or arching, but simply due to the creation of the river valleys. What has just been said does not mean that Uruguay has not had any ascending movement, which is precisely what occurred during the inter-era and querandine regressions, but that the cause of the appearance of the cuchillas was not a warping action, but the sculpturing of the valleys together with the fluvial undermining action.

A hypsometric representation, with level curves (and colors and shading) could reveal with great approximation the true form of the cuchillas, although for those of a lower degree topographic maps on a 1:20,000 scale or similar would be required.

In our country unfortunately there only exists the topographic map of Montevideo on that scale, but a larger part of the south of the country and some areas of the interior (Rincon del Bonete and artificial lake) and of the periphery (Salto Grande, Fortaleza Santa Teresa) were represented on maps on a 1:50,000 scale where the form of the cuchillas can be detected with a certain

clarity. This effort of the Military Geographic Service, however, continues. Aerial photography also has provided interesting documents regarding our relief.

The term cuchilla does not necessarily refer to the crested aspect which, according to the word which designates such forms could be expected; it refers to the functional hydrographic aspect already referred to earlier, namely that of separating the water in opposite directions. On the other hand crested reliefs exist in our country only where quartzites appear, such as in the Sierra de la Ballena and others. The character of real cuchillas is highly attenuated in the north of the country, where the predominant forms are level (level cuchillas, flat ridges, cuesta surface, etc.); this condition requires that the cuchillas of this country be classified into two main groups: a) rounded, as those in the center and south of the country, and b) flattened, as those of the north.

For the latter the expression "tableland" cuchillas has been proposed due to their flat aspect. The term did not please everyone, wherefore we will replace it with one which we used earlier, i.e. flattened cuchillas, especially since the flat ridges of the north of the country are residual tablelands and cuchillas such as the Cunapiru and others which appear on the landscape as spread-out tablelands.

The flattened cuchillas frequently appear as ridges with more-or-less accentuated scarps toward one of thier ends; others look like broad tablelands with very sinuous and at times scarped edges. The rounded ones have steep slopes such as part of the cuchillas of Dionisio, Otazo (Treinta y Tres) and Mangrullo (Cerro Largo). However, in general, these slopes are mild. For example, the general slope of the Cuchilla Grande de Durazno, located between the Negro and Yi Rivers, may be thought of, taking into account that the maximum altitude of the cuchilla in Molles is some 150 meters, and that from this locale to any other of the two rivers (located at a certain altitude above sea level) there is a distance of several tens of kilometers.

In general, on current maps the true aspect and significance the cuchillas have in our landscape has been detracted from. There

has been an almost general tendency to consider the cuchillas as true elevation lines developing over a lower and level terrain; even when secondary cuchillas were being represented, this type of representation is incorrect, because it leads one to believe that the narrow cuchillas, such as those which appear on these maps, are surrounded by level terrains, as though the fluvial valleys had been filled with sediments, which is the opposite of the truth in our country, where the effects of the erosion were predominant; on the other hand, the current scale of the maps makes it difficult to represent the undulations of a peneplain such as that of Uruguay. Hence on the orographic by A. Pochintesta the elevations had to be exaggerated with respect to the horizontal distances.

The name of sierra in our country is applied to greatly unequal reliefs. In some cases, such as in the Sierras de las Animas, Carape, Minas, the expression is used correctly; however this is not so if it is used to designate a monoclinic crest (and a succession of hogbacks) such as the Sierra de la Ballena or if it is applied to thie seas of stone such as the so-called "sierras" of the Mal Abrigo and Mahoma. The mountain chains of Lavalleja, Maldonado and other departments lack uniformity with the peneplain, in general constituting aberrations of monadnocks or evidence of erosion, and in many cases corresponding to the geological formations called series of Minas (or Lavalleja) and of Aigua, with which we will deal further on. In general the sierras consist of ridges connected at their bases and separate from each other; in the case of this separation not being present, they become asperezas [rugged terrain] (this is the case of the Polanco, Sepulturas and others). In general the sierras and asperezas constitute a wilder relief than the cuchillas, with plenty of outcroppings of high-resistance rocks (granite, quartz-bearing porphyry, ortophyry, quartzite) and offer at a distance a sawtooth physiognomy, due to the constituent ridges, although this aspect is not always peculiar to them; the throats which separate the summits may be called windows. The lower portion of the mountain slopes always appears covered with colluvial material where mountain brambles and meadows grow, at times quite thick.

Although the distribution of the sierras is highly irregular throughout the country, in general they predominate in the east, bordering at a certain distance the plain which swings around the Laguna Merin; as a whole in the peneplain they have the character of a subregion which still lacks true continuity. The same is true in Rio Grande do Sul where the mountain groups of Tapes, Herval, Encruzilhada and others rise in the middle of the peneplain resting on the crystalline base, and is called there "Rio Grande shield." The average direction of the mountain chains is from SSW to NNW, but the entire complex makes an enormous arc with its concavity turned toward the Laguna Merin. Aside from this lineup, there are mountains in Rivera, Cerro Largo and in the department of Maldonado itself (for example, the sierra Carape, oriented transversely with respect to the complex mentioned).

The constitution of these sierras is highly variegated in each case. For example, in the Sierra de Minas there are granite, porphyry, quartzite, etc. portions. In exceptional cases, such as in the Sierra de la Ballena the rocky nature is uniform over vast stretches, at least in general lines. Frequently the mountain masses divide into various portions due to the presence of epigenic valleys called gorges, which cut through them transversely.

> In reality not all the gorges (or ravines) in t in this country correspond to true epigenic valleys or gaps. A real one would be the Abra de Perdomo, in the Sierra de la Ballena (Maldonado), a famous passage which provides the link between Montevideo and the eastern part of the country.

In the sierras there appear to exist the highest points in the country. It is assumed that the peak of the Cerro de las Animas (located in the sierra of the same name) is the highest summit of the country, rising to 501 meters above sea level. Several ridges of the Carape and Animas mountains apparently exceed 400 meters. In turn, the well-known Sugarloaf Ridge, near Piriapolis, only reaches 400 meters and perhaps the ridges of Rivera and Vichadero and others, considered very high, are not that high.

> The reason why the highest peaks in Uruguay are in the southeast of the country and not in the north where various superposed

geological terrains exist is that the vascular movements the country has experienced at times went by which raised this portion higher than the others; furthermore the resistance of the rocks has intervened, although not in an essential manner.

The rugged terrain differs in general from the sierras due to its more massive configuration or due to the more irregular distribution of its component topographic forms, but at times certain forms of the relief are called indistinctly asperezas or sierras, as is the case in Aigua and Alferez. This lack of accuracy in the nomenclature is forgiveable since it is difficult to establish a clear difference between the two types of relief.

The typical seas of stone occur in the granitic zone and consist of vast accumulations of rock blocks, rounded by the processes of meteorization and frequently distributed on the mother rock, maintaining a highly unstable balance. Such blocks at times form groups and hence small mountains comparable to ridges, but this is accidental, since more frequently these blocks spread out over vast surface areas really giving the impression of a turbulent sea. Some seas of stone are merely slops of ridges that were dissected by the rivers; this is the case of the so-called "sierras" of Mal Abrigo.

> The seas of stones are characteristic of certain parts of Uruguay and although they depend on the types of rocks which originated them, they are fundamentally a result of climatic action. In Uruguay the erosive processes are sufficiently intense to drag along the products of meteorization and to isolate the stone blocks of the loose materials. In turn, in the tropical countries, these blocks frequently remain buried among the products derived from the meteorization. We will dwell on this point later on.

Forms of relief which attract our attention in the landscape and which are abundant in the country are the cerros (ridges) which vary greatly in shape, whereby it becomes difficult to classify them correctly. Some consist of simple colinas (hills) such as the Cerrito de la Victoria (85 m high), Montevideo, and the cerrito Piedras de Afilar (100 m) of Canelones. Some appear

isolated, in the case of Cerro de Montevideo (142 m) and others in groups as in the case of the Piriapolis ridges (Toro, Ingles or San Antonio, Espinas, at a certain distance from the Sugarloaf).

> K. Walther was the first one to try a classification of this country's ridges. In this effort it is advisable to relate the form to the geological structure or constitution. Regarding the former the aspect of the slopes should be pointed out (at times scalloped, as in the case of the Mirinaque ridge), of the peak (which may be pointed, crested, rounded, flattened, etc.), and the contour of the base (elliptic, circular, irregular). Some ridges consist of a single predominating rock material; this is the case of the Cerro de Montevideo, the anfibolite (basic metamorphic rock), the Arequita (the quartz-bearing or riolite porphyry), the Penitente (granite), the Sugarloaf (sienite) and Verdun (quartzite).

In the groups of ridges collective names are frequently used such as Tres Cerros de Cunapiru (Three Ridges of Cunapiru), Once Cerros (Eleven Cerros), Tres Cerros de Arapey, Cerros Hermanos (Brother Cerros), Cerros de Piriapolis, etc., especially when they have a common origin. Thus, for example, the Tres Cerros de Cunapiru derived from the gradual segmentation of a sedimentary tabular mass (flattened cuchilla) due to progressive fluvial action; hence its apparent lineup and its flattened peaks.

Aside from the forms of the relief so far indicated there are others of less topographic significance, which, however, are characteristic at times for given zones in the country; such are the slopes in the peneplain and they correspond to simple chunks of cuchillas; the sand banks which may be coastal (River Plate or Atlantic), the interior type (Tacuarembo, the shores of the Middle Negro River, etc.) and which may be mobile or fixed (the latter by natural vegetation or that planted by man); "towers" (such as the well-known "guardian" of the Gruta del Arequita), "candles" of the cuchilla of Dionisio, and small "buttes" or masses separated from larger complexes, commons where highly resistant sand banks crop out. Coastal zones rich in sand banks are those which are contiguous to the Cape Polonio (Atlantic coast of Rocha) and those immediately next to the mouth of the Solis Grande stream (on the side of Canelones).

Among the negative forms we note the riverbed, sometimes clearly resulting from the more recent epirogenic movements (this imbedding may be observed, for example, in the middle course of the Negro River, in part of the San Jose, and in other rivers), the depressions occupied by the coastal lakes, with whose origin we will deal later, the bays which cross the mountain lines transversely, and which sometimes permit the streams to cross the latter, such as occurs in the Maldonado Stream which crosses the Sierra de la Ballena in the so-called Perdomo ditch.

> The ditch of Perdomo has an epigenic origin, i.e., that earlier the Maldonado Stream flowed over less consistent materials than those which form the present Sierra de la Ballena; however, when the latter rose by the epirogenic movements, the stream was forced to imbed itself and it incided directly upon the hard rock (in this case quartzites) which it cut slowly until it produced the present ditch.

Dug out terrain is quite frequent in our country, some having a disorderly shape, which constitute the so-called "badlands" and others have a more regular shape following a more or less sinuous line of scarps. The coastal ditches such as those of Mauricio, San Gregorio and others are patterned by the alternating action of the river and of the waves. They pertain to what we will call here the inaccessible ditches; in those of Mauricio the level drop is 35 meters. Among the best-known river ditches there are those of Ofir (Rio Negro), Loros (Colonia), and the ones near the Fray Bentos.

> The presence of these river ditches in general indicates the edge which the rivers and streams prefer to attack but at the same time it points out the effect of the relatively recent epirogenic movement which forced the rivers to imbed themselves progressively. They therefore resulted from the so-called "erosion recovery." In the dug out ditches, aside from the pattern produced by the waves and river waters, the effects produced by the descent of materials due to gravity are important, with the water acting as a lubricant as the argiles materials become soaked up.

More spectacular than the ditches are the scarps, known in the north of the country, primarily in basalt terrain (cuesta scarp) and in the consistent sandbanks (scarps or slopes of the residual tablelands and flattened cuchillas). In the south of the country scarps occur on the flanks of the volcanic masses (for example in the Arequita cerro), in the fault mirrors (highly patterned by erosion) and in the contacts between the rocky masses of various consistencies nowdays completely sculptured.

A veritable line of scarps is formed by the eastern edge of the "basalt cuesta" which today is highly sinuous and irregular, due to the river action which imbed themselves increasingly within the basalt mass. This is observed in the departments of Rivera and Tacuarembo, in the eastern portion of the Negra and Haedo cuchillas, and in the so-called Sierra de Tambores. The complex forms a "front" subject to a constant retrogression due to the tributaries on the right bank of the Tacuarembo River (among them the Lunarejo, the Laureles and the Tacuarembo Chico).

There also exists an irregular and less continuous line of scarps on the edge of the tabular portion of the Santa Ana cuchilla and around the flat ridges which had come loose from them. At times, due to a lack of consistency in the sedimentary materials, these scarps were smoothed out considerably by river action. In the Cretaceous terrains of the Uruguay River Valley and nearby there appear scarps (in general of little prominence) where the sandstone or conglomerate cement experienced a certain amount of silicification or ferrification (this is the case of the Acollarados ridges, Paysandu, la Gruta del Palacio, Flores, with the latter presenting curious cavities).

A fact worthy of mentioning is the designation of sierra applied to forms of relief which pertain to veritable promontories of the basalt cuesta which spread out starting at the principal mass toward the east. Due to the sinuosities of these promontories as seen from lower level points they give the impression of successions of flat ridges or flattened mountain chains. An aerial inspection, nevertheless, showed us that we are dealing with ramification of the tabular mass, with which they are back to back. In Brazil these promontories are known

of "trunks" and in our country they appear in the so-called Sierra de Tambores and in the sinuous scarp of the Cuchilla Negra.

CHAPTER III

Geological Structure

General. Practically the entire Uruguayan territory is located on top of a very old crystalline rock formation which constitutes the "crystalline foundation" as designated by K. Walther (Crystalline Base), equivalent to the formations which elsewhere in the world are called "basement complex," archaic complex, etc. In general it is thought that a large part of the constituent material of these resistant shields must be relegated origin-wise to the Archeozoic era or at least to the Proterozoic.

> Due to the difficulties encountered in making a true chronology of these old bases they are dated back to a remote age which to some was the era when the first solid constituents of the earth's crust were formed. Today we know that the constituent rocks of these massifs are not always comparable age-wise and it is suspected that successive formations of material have existed following others which preceded them (granitizations). The present state of our knowledge regarding the Uruguayan crystalline base permits us only to conjecture about the development of these processes.

With this crystalline base as its oldest and perhaps greatly stable part the Uruguayan territory, as a whole, consists of a partially exhumed massif with its borders covered by relatively thick sedimentary formations (or by basic volcanic nappes), which are in disharmony with respect to the crystalline layer. In this sense, the geological and morphological aspect of the country recalls that of Morvan, a region in France, where a somewhat higher crystalline mass surges among the discordant sedimentary masses which

support themselves on the peripheral portion. It appears that the old crystalline massif in Uruguay is slightly arched by a bottom fold whose principal axis runs approximately from SSW to NNW, passing through the departments of Maldonado, Lavalleja, Treinta Trés and Cerro Largo in order, finally, to enter Rio Grande do Sul (Brazil). This massif emerges to the surface over an extent of some 70,000 km^2, neglecting many pampa mud parts which appear here and there, remnants of erosion, and some coastal sandstone which slowly progressed inland.

This shield is merely a portion of another larger one which occupies the entire eastern portion of South America, called Brasilia, which in the opinion of some geologists had existed in other eras (before the Cretaceous) connected to the principal crystalline mass of the African continent, and constituting with it plus large parts of India, Australia and Antartida, the Paleozoic continent of Gondwana.

The sedimentary cover (including the basic volcanic napes), which is supported non-uniformly by the crystallized base, becomes very thick near the Uruguay River, exceeding 2,000 m at the lower Dayman; there appears to be another one in the east, near the lower part of the Cebollati River, where successive faults appear to exist in the crystalline mass.

In the Rivera department a crystalline island rises to the surface through the sedimentary covers; it is likely that a phenomenon due to the exhumation of the massif is involved which occurred over the millenia, although it should be assumed that there were movements due to the folds on the bottom and along the faults.

In opposition to the constituent rocks of the crystalline base, and presumably Proterozoic, there are the materials which make up the Minas or the Lavalleja Series which on one hand include the metamorphic rocks which apparently derive from old sediments affected by the huronian movements and which were later displaced by the caledonians, and on the other hand, various volcanic rocks, with the acid and neutral groups being abundant (quartz-bearing porphyry and orthophydes, according to the old nomenclature). More recent materials, of unknown age and which include various rocks, have been relegated

to a series called Aigua, of which very little is as yet known regarding its chronological position. Therefore, and with only a probable hiatus in the Cambrian, and perhaps in the Silurian, there follows a sedimentary series which reaches from the Devonian to modern times, with major gaps in the stratigraphic column, and with basic rock strata, some of which, in the northwest of the country, are visible over an area of almost 40 km^2, and include basaltic spillings (Arapey or Cuareim lava), forming, as a whole, a hill whose surface appears to be mildly inclined toward the Uruguay River, leaving on the opposite side a relatively sharp but very irregular slopes.

Crystalline base. The components of the Archeozoic crystalline massif erupt over wide areas of the central and southern portion of the territory, including gneisses, highly metamorphized schists, old granites and diorites, with this entire complex appearing to be cut by frequent veins or dikes consisting of pegmatite, aplite, lamprophydes, etc.,

> The assumption that all the metamorphic granites and rocks of the country are Archeozoic has been rejected sometime ago. There are new granites which apparently cross the species of the Minas Series which is Proterozoic. For example, the granite (adamelite) of the Sierra Mahoma (San Jose) cuts and involves in the form of imbeddings masses of crystalline slates considered Proterozoic. Regarding the existence of gneisses of various ages, this fact appears to have been definitely substantiated. It is possible that some of the rocks which were previously located within the Archaic Complex in reality are pre-Cambrian (Proterozoic) and still date back to the beginning of the Primary era.

In our country, no findings have yet been made regarding the absolute age which characterizes the components generally relegated to the crystalline base. The criteria regarding the greater or lesser age of the rocks, taking into account the degree of alteration of the component minerals, in the other hand, is of relative value only.

The crystalline massif of Uruguay enters the

Brazilian territory in a visible form through the department of Cerro Largo and constitutes what in the neighbor country is being called the Escudo Riograndense (Rio Grande shield), an integral portion like our own crystalline base of the great mass of Brasilia, whose continuity ends at the latitude of Torres (Rio Grande do Sul) due to the presence of a powerful mass of basalts of the Mesozoic Age.

Aside from the old granites, gneisses, etc., already mentioned, including acid and basic dikes which cut through it, there occur in the massif migmatites (at times with ptigmatic folds which are very visible), amphibolites, hornfels, and dikes consisting of peracidites and diabases. With a certain degree of alteration some rocks are used as ballast; others, more compact, permit the extraction of stone axes and paving stones.

The massif appears arched about a principal axis oriented from SSW to NNE, and is cut by numerous faults (some of them proven directly and others assumed), some of which appear to affect the zone where the Laguna Merin and the submarine platform are located, which is scalloped.

Minas (or Lavalleja) Series. At times in frank oppsition to the crystalline base, the metamorphic components of this series are arranged approximately by a widening according to the principal axis of the bottom fold which affected the old massif. They appear in the departments of Maldonado, Lavalleja, Treinta y Tres and Cerro Largo, and simultaneously with them there appear to exist numerous volcanic acid and neutral masses which include quartz-bearing porphyries, orthophydes, etc. A Proterozoic Age is assumed for the complex.

The designation given to the series appears to be correct, which was not taken from the Lavalleja department and was called Minas, but from the capital, however it offers the inconvenience of being identical to another one used in Brazil. On the other hand, when the presence of interstratified conglomerates was established with the components of the series together with intrusions of apparently

different ages, it wasbelieved that a more recent series could be distinguished within the complex which some have suggested that it be called the Polanco Series. Regarding the chronology of the eruptive rock, many problems remain to be solved, so that there exists a suspicion that the diffusive or intermediate rocks which occur in the Sierra de las Animas, on the Piriapolis Mountains and in other zones are much more recent than certain porphyries and orthophydes which are contemporary with the schists characteristic of the series.

Among the most frequent metamorphic rocks of the formation let us indicate the quartzites (some are slightly sericitic) which led to the formation of monoclinic crests (for example the Ballena Mountain) hog-back lines and crested mountains; the slates which offer an extraordinary variety from simple lutites to strong quartz-bearing phyllites, mica-bearing and sericitic quartzites, the crystalline calcites, marble and massive dolomites and equistoses, the talco-schists and asbesto-schists. The volcanic rocks offer also considerable variety, with the acid or neutral species predominating. There are also calcareous tufa and breaches. It is possible that some crystalline calcites and volcanic rocks are of the Eopaleozoic Age (beginning of the Primary).

If we use the current nomenclature regarding the volcanic rocks, which omits the geochronological peculiarities of the materials, frequently difficult to demonstrate, the quartz-bearing porphyries of the series would be riolites and the orthophytes would be trachytes. There are also dacites, riodacites, etc. On the other hand, later intrusions in the metamorphic components of the series cut them here and there in the form of aplites, pegmatites, spessartites, diabases, etc.

The presence of phyllites, quartzites and some volcanic rocks in the region of Mal Abrigo and of the mountains of San Juan (department of Colonia) causes us to think that there existed specimens of the Minas Series. With respect to the volcanic rocks apparently porphyroclastic rocks are involed (milonites, produced by the

intense trituration of the materials, with the exception of some crystals). On the other hand, the presence of large masses of dynamometamorphic gneiss, recent granite, masses of peracidites (considered in the beginning as quartzites) and various basic rocks (amphybollites, diabases, spessartites) and hornfels require us to consider this formation as a special complex which could be called the Mal Abrigo Series, where the granite to which we have made reference would be later in age than the assumed specimens of the Minas Series. The rock dissolves in part as a consequence of the processes of meliorization and erosion in vast stone quarries or seas of stone. Such formations occur primarily in the so-called Sierra Mahoma (department of San Jose), but they also occur in the improperly called "sierras" of Mal Abrigo where a less massive granite exists, affected by an intense dynamic metamorphism.

Aigua-Lascano Series. Characterized primarily by the riolitic volcanic materials (mountains of Arequita, Lavalleja, Marmaraja, Maldonado and others) and by the andesitic materials (Lascano, Rocha), although there also appear sandstones highly affected by the andicite spillings (kilometer 145 of the Minas to Aigua Road); involved is a relatively complex series with a chronology difficult to determine, but presumably of the early Paleozoic Era (or Primary), although some have been assigned an even later age.

> The altitudes determined by the effusion of these riolites and andesites are somewhat flattened, slightly prominent, but characterized by generally abrupt slopes, such as those which occur in the Arequita Mountain. In the Lascano zone, the relief is milder.

Also of a difficult chronology are the sedimentary and metamorphic rocks, at times cut by basic dikes which constitute the so-called series of the Piedras de Afilar del Sur, Canelones department. Finally, and according with what has been said earlier, certain crystalline calcites (according to J. Goni) and some granites of the Cuchilla Grande, of the Guaycuru, etc., would be subsequent in age to the materials which make up the Minas Series, and could be relegated to the beginning of the Paleozoic Era (of the same age appear to be certain certain crystalline materials of the Tandil Mountain

chain, where, the same as in Mal Abrigo, milonites and recent granites occur).

Devonian Strata. A gradual ocean penetration, invading our present territory during the Devonian, caused it to assume the shape of a wide gulf which occupied the central portion of the country, although without becoming very deep; it soon withdrew, also gradually, not without leaving as indicators of its presence various strata ranging from arkoses and sandstones of varying thickness to very fine-grained sediments with an ample content of fossils. It appears that a veritable transgression is involved, and during the ingression sandstones of Carmen (today called Cerrezuelo arkoses) were formed; during the predominance or the apogee of the ocean invasion clay was deposited, partly mica-like (today called lutites, characterized by their marked fissility): when the ocean withdrew, the deposits corresponding to the sandstones of La Paloma (Durazno) were formed, generally covered with later gondwana strata.

From the geomorphological viewpoint, these strata offer little of significance, generally producing a rather regular topography; however, they are of great interest from the geological viewpoint.

> The so-called "clayey schists" of Rincon del Alonso which since 1955 we considered to be lutites, a name given to them now officially by our Geological Institute, contain a fossil fauna of brachiopods, mollusks and trilobites, with the most characteristic species being the Leptocoelia flabellites, the Orbiculoidea baini, the Schuchertella agazzizi, the Lingula lepta, the Derbyna elta, the Janeia uruguayensis, the Nuculites capensis, the Acaste signifer. The sandstones of the base at times appear to be silicified as happens in the Malbajar mountain and other places.

In practice these strata (belonging to the Devonian) constitute the beginning of our sedimentary series whose age is relatively well established, since the sandstones and other sediments of a previous age, which to some authors are Proterozoic and to others Paleozoic, pose a large problem.

It is possible that the invasion of the Devonian ocean corresponded to a period of the recession of the polar icecaps with the subsequent rise in the sea level. In turn, an advance of the ice occurred at later epochs when the Itarare glaciation occurred (permocarboniferous).

Gondwana System. Above the Devonian strata, or directly on top of the components of the old crystalline massif, there appear deposits of the sediments pertaining to the so-called Gondwana, the name of a gigantic austral continent which according to some geologists must have existed in earlier epochs consisting of part of the present land masses of South America, Austral Africa, India, Australia and perhaps Antartida. This continent later on moved and its various portions became isolated either due to the sinking of others or due to the progressive translation of some with respect to the adjacent ones, according to A. Wegener. The geological terrain formed during the epoch when there appears to have existed that continent, constitute the Gondwana System, to which the large basaltic emissions of the Parana Plateau in South America are related.

The basalts spilled over in successive nappes and at various points in Brazil their deposits alternate with those of the sandstones called Botucatu (the latter correspond generally to those which in Uruguay we call sandstones of Tacuarembo). In our country up to seven successive nappes of such spillings are found.

According to the modern viewpoint, the following complexes of horizons may be distinguished in the system which among themselves offer some more or less marked differences:

a) Eogondwana, which would include the permocarboniferous terrains such as Itarare and Rio Bonito, and somewhat above the so-called covers of Palerma and Iraty.

b) Mesogondwana, which would include the strata of Estrada Nova [New Road].

c) Neogondwana, which would include the sandstones and siltites of Buena Vista and the eolic sandstones of Tacuarembo.

d) Basalts (also called the Eruptions of the Serra Geral).

Even so, this scheme is subject to criticism since from a chronological viewpoint the sandstones of Tacuarembo and the basalt spillings would be of the same age. The entire system would have been formed between the Carboniferous and the Upper Triassic.

Our Geological Institute has proposed the following scheme: on the base, the glacial deposits of San Gregorio and the sandstones and lutites of Tres Islas [Three Islands] (with carbon top layers); this is followed by sandstone lutites and sandstones of Fraile Muerto, dark lutites of Mangrullo and clayey sandstones of Paso Aguiar. In turn these are followed by a discontinuity, the variegated clay deposits and the sandstones of Yaguari, and finally the red sandstones of Buena Vista. Another discontinuity separates these cover layers from the sandstones of Tacuarembo and the basalt spillings in general superimposed upon them (such spillings are designated "lavas" of Arapey).

It should be assumed that in view of the complexity of the problem presented by the Gondwana stratigraphy, all these schemes are of a preliminary nature.

Various sedimentary Gondwana cover layers include fossils (mollusks, fish or at least fish scale, water reptiles, ferns, etc.). On the other hand, part of the Itarare deposits (on the base of the system), also called glacial deposits of San Gregorio, were formed by masses of glacial conglomerates (tillites) and frequently present striated and fine varvite cover layers (pertaining to the sedimentation related to the recession of the ice). Regarding the sandstones of Tacuarembo, sediments of a fine, rounded and dull grain are involved, with frequently crossed stratification, originating under a desert regime (paleodesert of Botucatu).

Basalt Spillings. Eruptions of basic lava which occurred in a relatively tranquil form, and through numerous fissures, took place during the last years of the Triassic period (the Mesozoic era). The lava spilled over a continental surface of approximately 1 million km^2, some 40,000 of which pertain to the Uruguayan territory. At various points (for example the northeast of Rio Grande

do Sul and primarily in Tres Forquilhas they attained thicknesses in excess of 1000 m (540 m maximum near the Lower Arapey, and some 1000 m near the final portion of the Dayman, in Uruguay).

The spillings are composed of a succession of nappes (up to six or seven in Uruguay and thirteen in southern Brazil) where in general the base portion is solid and the upper portion rich in holes, and at times geodes and amygdalæ (filled with calcedonia, quartz, zeolites, calcite, etc.). The middle portion of each nappe almost always has a column-like structure, comprised between the upper and lower masses rich in horizontal diaclases ("laminar structure").

> Particularly in the zone of A. Catalan and some of its tributaries (primarily the A. Catalan Chico) the geodes are abundant and frequently contain the amathist (violaceous) variety of quartz, at times in large crystals. There are also valuable agates as well as other worthwhile silicon minerals.

Apparently the spillings were supplied by a multitude of fissures, opened in the subjacent rocky mass; among the latter, the Tacuarembo sandstone has suffered a slight metamorphosis, remaining in the form of a compact and hard material (slag and vitrified sandstones). The vitrified sandstones form curious dikes which cross the basalt mass and on other occasions they form boles and banks which apparently rose due to a difference in density.

The dikes mentioned appear to have been formed under great pressure (due to the enormous vapor and gas tension which impelled the subjacent sandstone through the fissures). Some are pink or flesh-colored and other are greenish or grey. The material was used by the primitive people who lived thousands of years ago in our country (according to discoveries by A. Taddey).

The complex of basalt nappes is inclined mildly toward the west or the southwest, and disappears in the latter direction under relatively recent strata (from the Cretaceous to Quaternary); on the opposite side, a line of cliffs indicates the edge of the "cuesta", where the basalt still protects the subjacent sandstones against the erosion effects. The lavae exist in the vicinities of these cliff lines, forming flat mountains, sometimes in straight lines,

and in some cases their upper layers are highly silicified or vitrified due to their previous contact with the volcanic nappes.

> The age of volcanic activity has been definitely established as the rectic (the final phase of the Triassic). Another group of basic lava was found northwest of the city of Treinta y Tres and where the Puerto Gomez perforation was made near the Cebollati River; these emissions do not pertain to those of the northwest of the country due to their distribution, for which J. Goni suggested the name of "lavas" of Arapey.

Influence of the Gondwanides on the Terrain. It has already been stated that the sandstones, on becoming silicified and vitrified, produced the flat mountains or successions of residual tablelands (for example, the Three Cunapiru Ridges). These forms also occur when the basalt appears but here the principal characteristic is the presence of cliffs and a scalloped landscape ("trapp"). Frequently, what appears at a distance in the landscape as a succession of ridges, are merely enlargements of the tabular basalt mass (these enlargements are called trunks in Brazil and here we call them basaltic promontories).

Since rocks of a certain consistency are involved, the rivers excavated them in order to give rise to ravines (valleys with steep walls). An example is the so-called Eden Valley in Tacuarembo. The sandstone masses at times are cut up into chunks, giving the landscape the shape of ruins, with more or less isolated "buttes," "towers," and other smaller forms (one example of this class of terrain may be found near the Cuervos grotto in Tacuarembo).

Finally, due to the thousands of years of fluvial work, begun early in the Cretaceous, the great masses of sandstones were dragged along and the great depression of the Tacuarembo River was formed, which we will deal with later, and where more resistant portions which today constitute veritable evidence of erosion, remained (residual tablelands and flat mountain ridges.

> From the economic viewpoint, the presence of bituminous schists and pit-coal is of interest in the Eogondwana cover layers and on the basalt envelop minerals of the silicon group

(quartz, chalcedone, agates, etc.). Also of interest are the clay, sandstone and the ochre. Nevertheless, in the case of the pit-coal and of the bituminous schists the quantities involved are exiguous and practically non-exploitable.

Cretaceous Terrains. Basically they include the so-called Guichon sandstones, frequently with a highly visible stratification and containing fossil residues of crocodiles (of the Uruguaysuchu type), and in the higher portion the sandstones and conglomerates (those which frequently are conglomerate sandstones) of Mercedes, with an intercalation of calcites, covered at times by the Asencio sandstones, a group to which the ferruginous sandstone of the Palacio belongs, probably a fossil lateritic material. In the upper layers there are dinosaur fossil residues.

The conglomerate sandstones frequently present a marked superficial silicification, while the sandstone of Palacio gives way, upon being subjected to meteorization and erosion (and partial dissolution) to a curious column-type formation such as the one found in the famous Palacio Grotto, department of Flores, which some attribute to human hands.

The topography developed above the Cretaceous strata in general is mild, except when the silicification lends greater consistency to the materials; this then leads to cliffs (for example, in the Acollarados Ridges, in Algorta, etc.), or tablelands of medium elevation (this latter group includes the famous Meseta de Artigas, next to the Uruguay River, in Paysandu, and the Claveles Ridge, department of Soriano, which was visited more than a century ago by the great naturalist Ch. Darwin.)

The Cretaceous terrains are located in a part of the Santa Lucia riverbed, in the valley of the lower Uruguay River, and form large fragments in the middle of the country. It is generally moderately thick. It is assumed that the accumulations of ore fragments which today constitute the conglomerates and conglomerate sandstones of Mercedes, were formed under a torrential regime; a tropical climate must have prevailed when the deposits of a large part of the Asencio sandstones were formed (particularly, the ferruginous sandstones of Palacio).

Cretaceous terrains also emerge in the Santa Lucia riverbed and along the Cuchilla Grande del Sur (Canelones).

Tertiary and Quaternary Terrains. In the depressed valleys of the Cretaceous cover layers, calcites left slowly by the evaporated water accumulated, permitting the concentration of material; part of these calcites silicified and when the fluvial erosion cycle took place, due to this silicification, which gave them great consistency, they finally became salient shapes in the terrain, producing broad ridges which may be seen, for example, along the Queguay River (the ridges of Buricayupi, Tigre and others). Hence the name of Queguay Calcites which was given to these deposits, in part highly silicified, and in part not.

> The silicification (in this case by substitution) led to the creation of carneolite masses, of beautiful pink and flesh-colored hues, a material which the Indians used in modern times to manufacture their arrowheads, spearheads, etc. On the other hand, the same process, while giving consistency to the materials, thus making them more difficult to be affected by meteorite action, favored the formation of hard rock masses which are a major obstacle to the river streams (a good example is the Queguay waterfall); in turn, the Chico falls, which are very steep, and the Grande falls of the Uruguay River were influenced by the presence of basalts which involve chunks of sandstone slag.

The Queguay calcites occupy an exiguous area, but they appear in various departments (Paysandu, Rio Negro, Durazno, Canelones, etc.); they contain some fossils, apparently of aquatic species.

Temporarily, the Oligocene age (of the Cenozoic era) has been assigned to the terrains, followed immediately by the so-called cover layers of Fray Bentos (which should preferably be called "calcareous mud" of Fray Bentos), probably Miocene, and in general poor in fossils. They appear principally in the valley of the Lower Uruguay, in the vicinity of the River Plate coast of the southwest, and in the Santa Lucia river basin. From this mud a soil of great fertility has been derived, and the decisive influence these materials have had in the formation of high-productivity land has

become proverbial, being located in the so-called "wheat zone."

The influence of the Fray Bentos mudflats on the topography is minor but because they are cut by the fluvial streams, they form at times spectacular ravines (Ofir, on the Uruguay River, La Barra, near Santa Lucia; Fray Bentos, etc.). Apparently there are sediments of terrestrial origin involved which offer some similarity with the pampa mud flats of more recent origin.

Above the Fray Bentos, but in general, next to or at a small distance from the Uruguay River or of the River Plate coast, there are the terrains pertaining to the Entrerrian transgression, which can be seen in Camacho (Viboras stream), Nueva Palmira, Punta Gorda (Colonia) and other places. In Punta Gorda, where, according to some, the Uruguay River would end, such terrains, superimposed upon the mud mentioned above, are distributed as follows: directly above the Fray Bentos cover layers there appears a greenish coarse layer, and further up a very fine sand, practically without cement, which easily yields when the upper layers fail to protect it; above this sand mass, there are at times clay layers which then give way to more or less compact banks, very rich in fossils and calcites, terminating in an upper fossil-bearing layer which is more fragile and of a somewhat different crystal face.

> The sandstone contains as a typical fossil, however, not abundantly, the Lingula Bravardi; in the calcite layers we find numerous molds of Venus muensteri, Cardium robustum and less commonly Cymbiola brasiliana, Monophora darwinii, Myochlamys paranensi, etc. In the brittle and higher zone there are various species of Ostrea.

The succession indicated for Punta Gorda (Colonia) repeats further up north, in the Barranca de los Loros, in Nueva Palmira, etc., but the Capas de Fray Bentos layers appear higher, and the facies of the inter-river terrains change according to the various localities. Involved are Pliocenic deposits, which rose as a results of the rise of the coastline and the consequent regression of the sea.

> In the so-called Bautista or San Francisco ridge there exist fossilized shark teeth which reveal that those selachians came

this far. On the other hand it is known that the inter-era sea penetrated the continent deeply up to approximately the present edge of the Sierra de Aconquija and the borders of Paraguay. It is impossible to doubt that the deposits which exist in Uruguay, linked paleontologically to those which occur in Argentina, pertain to different processes; hence the designation " Inter-era terrains" must continue being used without change of designation.

Apparently the regression of the inter-era sea occurred rapidly, with major changes in salinity, perhaps due to the contribution of river water. It is possible that at that time the Parana, which should run through the present estuaries of Ibera and the Central Rio Grande Depression (where the Ibicuy and Yacuy rivers now flow in the opposite direction) toward the Laguna de los Patos, was diverted and together with the Uruguay River was forced to penetrate the River Plate gulf which was in full retreat.

What has been stated above corresponds to a hypothesis worthy of being sustained because it is difficult to explain the enormous amount of sand accumulated on the Rio Grande coastline, which cannot be only of oceanic origin nor can it have been brought simply by the Yacuy River.

The inter-era deposits occupy the coastal zones of the department of Colonia, but they also appear in San Jose (Arazati) and they are more than 100 m deep in Rocha (Chuy).

We should also consider Tertiary terrains the sandstones which are greatly silicified and at times conglomerates of Salto, probably derived from river deposits and which today form a somewhat considerable area near Salto, and another one in San Javier (Rio Negro). From the desilicification of these sandstones there resulted sandstone and later on soils which are taken advantage of to plant orange trees.

Although the residues of mammals (Uruguaytherium, Megalonychops) and birds (Devincenzia) display a fauna development of some size in some of the Tertiary terrains so far indicated, it is in the so-called Pampean Formation

(which some have proposed to call Arazati, in Uruguay) that we observe a truly extraordinary fossil wealth, particularly concerning the variety of mammals; among these there are the gliptodonts (Panochtus, Doedicurus, Glyptodon); the gravigrades, animals which are frequently very large (Megatherium, Mylodon, Lestodon, etc.), the noctungulates (Typotherium, Toxodon), the felidae (Smilodon) and the strange representatives of the Macrauchenia and Mastodon class (distant relatives of the horse and the elephant); the rodents left residues which reveal their abundance.

The Pampa Formation, assigned to the end of the Tertiary and the beginning of the Quaternary, is quite uniform and does not present any clear stratification, nor any discontinuities of any magnitude among its various portions while they appear to be chronologically different. The loess of the upper portion contains more calcite concretions and appears to have a dominantly eolic origin, containing a certain amount of volcanic ash, very fine sand, argil, etc., although in variable ratios; the concretions, at times quite numerous, form a veritable composite and originate the so-called loess puppets, more compact than the lime itself, but of weak cohesion. The pampa terrains spread out throughout the country over a vast area, but they are discontinuous and have been subjected to an intense accelerated erosion due to the indirect intervention (and at times direct) of man. They abound in the southwest of the country, but they also exist in Laguna Merin, in the center of the Republic (Florida and other departments) and may also be found in Artigas (Tres Cruces stream, Cuareim river, etc.). Some authors consider the post-Pampean only Quaternary (or post-Arazati).

The deposits of the Querandina transgression are superimposed upon those of the Pampean Formation although they may be found directly above the crystalline base; they are marginal throughout the country (Lower Uruguay, River Plate, periphery of Laguna Merin). They contain a varied fauna of subfossiles, especially of Erodone (Corbula) mactroides, Mactra isabelleana, various Mytilus and Ostrea puelcheana. At times they contain gravel and are highly sandy.

Completing the group of Quaternary terrains there exist turf materials, plaster argil (Bellaco), coastal sandstone, colluvial deposits, alluvial deposits, etc. The turf terrains occur along the River Plate coast

and in the river basin of the Laguna Merin, in the zones of the former marshlands, where a dense vegetation of red mace has developed (Typha angustifolia, T. latifolia). Cyperaceae (Scirpus giganteus, S. californicus, Carex Tweediana, etc.), red sarandi (Cephalanthus glabratus) and other various helophile plants. The quality of the turf is average or low. Apart from the River Plate and Atlantic sandstones which form at times groups of mobile or fixed sand banks, there exist Quaternary sandstones along the middle course of the Negro River, next to the Uruguay River and elsewhere.

The subfossil kerantine deposits, located between four and eight meters above the present level of the River Plate indicate apparently a coastal rise in modern times, although it is difficult to establish whether a rise of the terrain or the withdrawal of the waters is involved due to the eustatic movements (oscillations of the sea level).

Summarizing what has been said so far with respect to the geology of the country, we can point out the following facts:

1. There exist in Uruguay geological terrains of all geological eras and almost all geological periods; no Cambrian or Silurian terrains per se are known as yet, although, according to what has already been mentioned, it is possible that some calcites, marbles and perhaps certain recent granites belong to these periods.

2. The terrains corresponding to the crystalline base crop out in vast areas, followed by Triassic basalts.

3. Several epochs of volcanic activity existed in this country, primarily during the Precambrian (Proteroizoic) and the Triassic. The principal ice coverage affected the country during the Permocarboniferous (Itarare and San Gregorio). A very dry climate existed during the Triassic (paleodesert of Botucatu, represented in our country by sandstone deposits of eolic origin in Rivera, Tacuarembo, Artigas and Durazno).

4. The territory was affected by various ocean transgressions; the main ones occurred during the Devonian,

during the Tertiary (intra-era) and the Quaternary (kerandine).

5. The patterning work which led to the present relief began its definitive work starting in the Cretaceous and further intensified during the intra-era regression.

6. From the viewpoint of economic geology the country is poor in usable minerals except for construction stone, sand, argil, calcites and marble. Iron and manganese can be used, but their deposits are highly localized; combustible minerals (soft coal, petroleum) practically do not exist. We will return to this subject upon discussing production in general.

7. Since the crystalline massif presents great stability, the country does not experience major seismic shocks; there are no indications of recent volcanic activity. In Arapey a 40°C thermal spring exists.

8. We know very little of our Quaternary stratigraphy. Neither are we able to decide together with J. Frenguelli whether the entire Pampa Formation is Quaternary. On the other hand, it would be interesting to verify the indirect influence of the Quaternary ice covers on our territory and determine the fluvial periods or epochs characterized by dry climate. At any rate, some rounded terraces, of median cement content, such as those of the Catalan river basin (Artigas) appear to correspond to fragments of ore, which today are cemented in, of the last glacial era.

The first serious investigations regarding the geology of our country are due to D.A. Larranaga who in 1819 wrote a report regarding the formation of the River Plate derived from the fossils that exist on its banks; this work was published as recently as 1894. In 1830 C.W. Weiss revealed some results dealing with the collections of F. Sellow in our country and in Rio Grande do Sul (called San Pedro province) between 1821 and 1823. The contributions by A. d'Orbigny were very important , who, according to what we have seen, was in Uruguay before he undertook his great travels in the interior of South America and Ch. Darwin, who gathered collections and made observations published in the Geological Observations for the first time in 1851. During the second half of the last century the following individuals wrote or dealt with our geology: H. Burmeister, who became director of the Buenos

Aires Museum, C. Twite, who dealt with economic geology, J. Creavaux who dealt with the assumed erratic blocks which to some were an indication of South American glaciation, F. Ameghino, a tireless paleontologist, C.W. Gumbel, who dealt with certain minerals contained in our basalts, including waterstones, and T. Vilardebo.

K. Walther gave a brief review on the visit Ch. Darwin paid to our country which includes a geological description of the Claveles Mountains which the famous British naturalist reached during his trip through the interior of Uruguay. Regarding the work by Larranaga his memoirs relative to the River Plate were published and can be found in the Museum of Natural History.

During the 20th century, geological research increased throughout the country, primarily thanks to the continuous and fruitful labor performed by K. Walther to whom we owe a large number of valuable publications containing much original material by the author. His "Fundamentals of the Geology of the Eastern Republic of Uruguay" of 1919 represents a great milestone in the advance of geological knowledge of the country. Contributions of great value were presented by C. Guillemain, K. Wilmann, J. Falconer, who dealt especially with the Gondwana terrains, J. MacMillan, who worked on the crystalline base and the preceding series, P. Groeber, E. Terra Arocena, who was the director of the Geological Institute, R. Lambert, who aside from other work produced a synthesis regarding the geology of the country. In the field of paleontology and stratigraphy L. Kraglievich and J. Frenguelli distinguished themselves. F. von Hoehne, L.R. Cox, H. von Ihering, M. Lugeon, C. Rusconi (who classified the fossils found by J. Aznarez, contributing to a better understanding of the Uruguayan Cretaceous), contributed data, classifications and studies of interest; A. Teisseire who published a monograph on the geology of the surroundings of Colonia and A.L. du Toit, a great defender of the theory of the continental drifts who published a comparative geology between Africa and South America. A summary regarding the mineral deposits of the country was published by R. Marstrander (1915).

Recently the following distinguished themselves with their work in geology: J. Caorsi, N. Serra, Juan C. Goni, H. Gordon Jones,

L. Buquet, D. Rey Vercesi, contributors to the efforts of the Geological Institute. The same can be said for R. Mendez Alzola, who did work as a paleontologist. With respect to the petrology and the study of minerals the following should be listed: Juan C. Goni and J. Chebataroff for his studies of rock alteration and physical geology.

CHAPTER IV

Origin and Evolution of the Terrain

Soils

Predevonian terrain. Prior to the advent of the Devonian transgression (in the mid-Primary Era) which permitted the sea to advance on our territory and which left there a series of deposits before withdrawing, the crystal massif must have undergone intense sculpturing whose reconstruction today is almost impossible. What is already certain is that when the deposits were left, the massif already presented innumerable dislocations, folds, etc., and on the surface offered a highly complex terrain which was later on subject to the intense glacial action of the permo-carboniferous (the Itarare floor). The Devonian sediments were deposited on this surface and were followed by those of the Eogondwana in an irregular form. We already said elsewhere that parts of the former massif were passed over by the volcanic lavae which left accumulations and spillings during the same epoch when the constituent sediments of the present metamorphic series of Minas were dislocated (or Lavalleja), whose more resistant specimens (quartzites) as well as some of the volcanic masses mentioned (quartz-bearing porphyry, mainly) led to irregularities and groups of hills in the mountain region, causing the soil to be highly irregular.

An examination of the rocks and structures of the old massif presently reveals that its constituents were subject more than once to intense tectonic pressures and to intrusive effects of the more recent rocks in the form of dikes, apophyses, batolites (Sierra Mahoma, Maldonando Willow) and bed-by-bed injections, until migmatites were formed affected by thin ptigmatic folds (Colonia). It is possible that the major tectonic Huronian movements were not unrelated to these structures,

and later it was the influence of the Caledonian movements (or others chronologically comparable) which were responsible for the deformations, dislocations and igneous intrusions.

One important effect was produced also by the granitization processes which are presumed to have followed the appearance of the volcanic rocks of the Minas Series (or Lavalleja). In this case also the dikes, the apophyses, the batolites, as well as the pressures and resulting contacts modified the earlier formations.

From these intrusions (primarily granites, granodiorites and various phylonian rocks) clastations on a large scale resulted (the formation of milonites, quite frequent in the Mal Abrigo region) and dynamo-metamorphic structures (gneissic granites, such as those in the southern portion of the Mal Abrigo Mountain).

All these processes in their majority are of a geological and not of a geomorphological nature. Of the forms of erosion and the sculpturing processes which affected the crystalline massif prior to the Devonian we known very little. With respect to the Minas Series it is interesting that there are conglomerates, lutites (argil schists of easy fissure) and other materials which may be used as a key in the reconstruction of the sedimentary processes of those epochs and of the conditions under which they were produced.

Before the Devonian sea invaded our present territory, the crystalline massif offered a relatively complicated relief which had been affected by Huronian movements and later by the first phase of the Caledonian movements, although this chronological relationship is merely a likelihood.

The regional descent of the massif produced the entry of the sea mentioned above and inverse movements which continued for a long time and caused its withdrawals. The continuation of the ascent of the crystalline massif must have occurred much after the permo-carboniferous glaciation which intensely affected the materials of the shielding, thus reducing its elevation due to the destructive action. During the Devonian as well as throughout

the glaciation, sedimentary deposits were produced.

Postdevonian evolution of the crystalline massif. A deep fold of large amplitude permanently arched the crystalline massif after the Devonian; it is possible that this arching was accompanied by major dislocations, primarily following the basalt spillings which covered part of the Gondwana " strata. Furthermore, flexures and dislocations occurred in the zone where presently the Laguna Merin is located, surrounded with relatively recent sedimentary covers, but under which vast masses of basalt exist. The exact period of this arching cannot be established which elsewhere occurred in phases throughout entire geological epochs. It is possible that its definitive completion occurred in eras prior to the Cretaceous deposits which are practically horizontal as a whole.

The arching follows an axis oriented from SSW to NNE which begins on the River Plate coast of Maldonado and passes through the Cerro Largo into the Rio Grande do Sul territory, where it continues until it merges with the main axis of the elevation line of the Serra do Mar. Involved is the entire warped edge of eastern South America, accompanied by secondary archings and dislocations; one of the latter passes through the so-called "crystalline island" of the river and that of the Cerros Blancos.

One of the main causes of the arching appears to have been its isostatic nature: a sinking on the one hand of the middle portion of the South American continent under the increasing load of sediments and basaltic nappes, and on the other, of the bottom of the Atlantic, also loaded with deposits of continental origin. The arching was accompanied by dislocations and due to the inclination of the Gondwana covers and the basaltic nappes of Uruguay and Southern Brazil toward the west. This dip does not greatly affect the Cretacean and Tertiary covers, a fact which leads us to think that the arching in general corresponded to Precretacean times, although this statement can only be made tentatively. Involved is a fold with a large radius of curvature (i.e., the arching of a vast area but doubled very

slightly) accompanied by arching of secondary importance which affected the crystalline base and the constituents of the Gondwana system. On the structural map of South America by F. Ruellan the axis of this deep fold continues northward through Brazil up to the state of Ceara.

After the withdrawal of the Devonian sea, the surface of the crystalline massif was patterned by erosion cycles which followed each other up to the beginning of the permo-carboniferous when an intense glaciation left its marks on the old shield. Part of the Devonian deposits was destroyed or reduced with respect to their original size; the glacial actions which affected the territory, on the one hand produced erosive phenomena and on the other glacial deposits (glacial conglomerates or tillites, varvites, erratic blocks) which today contitute the geological terrains we call "the glacial terrain of Itarare or San Gregorio" which exists in Cerro Largo, Tacuarembo and in the departments nearby.

Near the artificial lake of the Rio Negro in the San Gregorio zone, erratic blocks appear, known also elsewhere. Varvites, tillites and striated rocks have been found at many points.

The glaciation must have lasted for a long time and produced intense patterning effects, dragging the crystalline surfaces and transporting the materials over great distances. According to Falconer, the present edge of the crystalline shield in the department of Cerro Largo was originally oriented from east to west, due to a major primitive extension of the glacial deposits, which were reduced in size by the erosive actions which followed the withdrawal of the ice. Fruthermore, there existed in the above mentioned department, and extending through Tacuarembo, a valley where a good part of the sedimentation of the materials of glacial origin was produced, and through which the vast glacial tongues must have been sliding, which with the changes in climate continued decreasing in size until they could be found only at the highest elevations. The climate apparently became warmer and then there was a time which was favorable to the deposit of the so-called Rio Bonito sandstones (or Three Islands, according to a new nomenclature proposed

in our country.) Falconer assumes on the other hand that the separation between the Rios and Acegua (Cerro Largo) Mountains happened in another major epoch and its approximation was probably due to the arching or folding in depth mentioned earlier. The definitive glaciation lead to a progressive exhumation of the crystalline massif in the higher parts and its coverage in the lower parts or in the folds which were favorable to deposit formation. Later on, sedimentation became more intense, and occurred in the deeper river basins and swamps, but it is likely that it did not occur in the higher regions of the crystalline massif. Until the Upper Triassic (secondary era) an arid climate prevailed, under which finer materials were produced (desert sand) which were dispersed by the wind over considerable areas (paleo-desert of Botucatu). It is possible that under this climate the materials of the crystalline massif experienced a marked decomposition.

> Although we confine ourselves here to pointing out primarily the patterning which happened under abnormal climates (glacial and desert) it is easy to understand that during a time lapse as enormous as that between the Devonian and today other patterning forces must have been active whose tracks are less well preserved or more diffcult to interpret. In the sedimentation traces and in the characteristics of the fossils of some Gondwana terrains successive climatic changes may be assumed, with the sedimentation occurring under always changing conditions. It is possible that the normal patterning (predominant fluvial action under sufficiently humid climates in the absence of glaciation) took place over a period of extended epochs.

At the end of the Triassic the basic lavae spilled over vast surfaces, including directly, the crystalline massif (basalts in general) which locally interupted the earlier patterning cycles. During the Cretacean, the erosive action, although it affected the crystalline masses, permitted the deposits of sedimentary cover layers in certain river basins (primarily in the western part of the country) some of which (the comglomerates) are

evidence of the presence of torrential regimes and others of ferruginous (Palacio sandstone, for example) the predominance of a tropical or sub-tropical climate.

In the periods following the Cretacean, the crystalline base was laid bare over appreciable areas due to the partial destruction of Cretacean deposits and other earlier ones (primarily Eogondwana). , The reliefs of ridges, mountains, irregularities, etc., formed on the surface of the massif which presently characterize the crystalline peneplane. When the intra-era regressions between the Tertiary and Quaternary Era were formed, a rejuvenating on the surface of the massif occurred, and the coastal chapes rose (for example, certain lateral cavities at Ballena Point were produced by the pre-querandi surge and they are now protected against such action).

The influence of these rejuvenating effects mentioned, however, has not been shown with sufficient clarity; however, we can state that their consequences may be detected in the sedimentary terrains (particularly on the fluvial terraces and coastal ravines). In the crystalline mass surfaces which agree level-wise and developed over masses which terminate on the slopes of the mountain ridges.

Patterning of the Primitive Terrain Up to the Crystalline Peneplane Phase

A large part of the system of ridges frequently called the system of the Great Ridge was created above the crystalline shield, whether by the direct erosion of it or by previous exhumation of the massif due to the destruction of the sedimentary cover. The major portion of the patterning work was due to fluvial action, aided by chemical meteorization. The creation of the ridges therefore did not result from true uprisings of the ground, but from the formation of the valleys that separated due to fluvial water action. It may be said that in Uruguay the relief is a function of the hydrographic network since it is its primary creator. At any rate, the effect produced by a variety of rocks and structures on the diversity of the shapes should not be underestimated.

Due to the structural influences and the rock constitution, the mountain valleys are

frequently asymmetric. There are various altitudes of the ridges. Many outcroppings revealing greater resistance to the effects of meteorization and erosion appear (in the case of quartzites, enlarged crests are involved which can sometimes be detected at great distances). The varying alterability of the materials in this sense is of great importance; thus, for example, since highly friable rocks are involved or those which are exceedingly inalterable, the production of seas of stone did not take place; furthermore, the structure had a decisive influence in their generation. (Primarily disintegration into banks, due to the particular shape of the diaclases). Materials such as phyllites and marble, and in general gneisses and alterable schists yielded more than certain granites, porphyrites and quartzites.

Due to their intrinsic nature the crystalline plain is a very old unit, presenting a mature relief, interrupted only by the rejuvenations which took place due to the intra-era and Querandi movements. The landscape may be described as slightly irregular with frequent rock upcroppings and residual forms due in large part to a marked resistance of the rocks to the unfavorable structural conditions for an effective attack of fluvial erosion. Recent alluvial and colluvial materials are relatively rare throughout the entire crystalline massif and the colluvial materials abound more along the slopes of the mountains and the ridges of the Minas and Aigua Series.

For example, at the foot of the well-known Arequita ridge (Lavalleja) the mass of quartz-bearing porphyry (riolite) is surrounded by a powerful accumulations of colluvial materials (moved by gravity) among which we distinguish enormous surface blocks which at times are polished (friction surfaces corresponding to original extrusion movements).

The existence of stone seas in the country, the scarcity of colluvial materials, etc. show that here, and under the present climate as well as that of the recent geological times, the erosive action and transport

has been sufficiently rapid to haul the excess products resulting from the meteorization or alteration of the materials. The opposite is true in certain portions of tropical Brazil where the rock blocks are very rapidly altered or buried by finer colluvial masses; the typical stone seas are absent and the colluvial deposits become very thick.

The creation of a peneplane relief was enhanced by the long time which elapsed, the work of the fluvial action, and the chemical alteration of the materials. The epirogenic movements, which produced periodic rejuvenation, consistently raised the mass of the crystalline shield exposing it to the patterning effort. One should not think that the primitive crystalline forms of the country were ever very high. Apparently, in our territory, the particular case occurs where there has been a certain equilibrium between the destruction caused by the patterning action and the elevation of the relief as a result of the isostatic movements. Hence the application of the Davis concepts to the interpretation of our relief presents some difficulties. At any rate, what the patterning effort has left us through the post-Cretacean times is a mature relief with abundant "hartling" of resistant materials (evidence of erosion).

The intra-era and Querandi regressions caused resumptions of erosion which influenced the patterning of the crystalline formation, but in general, the ruptures of the slopes of the mountains or of the valleys were the consequence of varying resistance in the rocks, their particular structures and their degree of alterability. The chemical meteorization, more effective in shady areas (which in this country face south) was caused by an apprent retrogression of the patterns toward the north; this is the case of the porphyry mass of the Arequita ridge and other similar elevations. The sturcture is responsible for the local presence of rectangular fluvial networks which occurs in part of the Maldonado department (the Maldonado, San Carlos and other streams), for the scalloping of the slopes, the asymmetry of the valleys and the enlargement of some forms (several quartz ridges

of the Minas Mountain and those near the Penitente ridge).

Until recently the mountain ridges presented themselves as being directly related to certain forms of the terrain of the continent, i.e., elevation lines resembling mountain chains. In reality, all these undulations which are the watersheds of the river beds, originated neither due to folds nor to dislocation, nor to volcanic action. This does not mean that the Uruguayan terrain has not suffered such movements. To the contrary, we saw that in times past folding actions traceable to the Huronian and Caledonian times took place, together with great archings in depth, the result of fractures and faults, the accumulation of volcanic lavae and the slow movements of an isostatic nature. The error of the maps has been to represent the ridges as non-continuous lines on a level terrain which is in contradiction with the truth; even today, maps are being published where the systems of representation in the form of "caterpillars" according to the expression used by K. Walther, are quite popular. Genetically, the ridges correspond to the excavation or the carving out of the fluvial valleys in the original mass of the massif and of the irregular formations that are adjacent to it and which cover it. In each of the major valleys which are becoming deeper and wider, there emerges slowly a mass of territory which is increasing in elevation with respect to the levels of the rivers that outline them; the affluents of the latter suggest valleys which tend to segment the principal mass in others of smaller size; thirdly there is the work of the sub-affluents which provide a new subdivision of the forms and so on. A dendritic dense network performed this work throughout Uruguay, resulting in a slightly rolling surface, without leaving out "monadnocks" or "hartling" due to the resistances of the materials and due to the special structures (involved are remnant forms, evidence of erosion, an example being those of the Montevideo ridge).

This incision of the fluvial network was aided by the epirogenic movements of ascent and apparently by a slight increase in humidity and the climatic pluviosity of the recent millenia; when the terrain rose, rivers and streams resumed their erosive work; the same effect was produced by an increase in the pluviosity. The most important movements lead to a narrowing of the network,

a fact which resulted in rivers such as the Rio Negro (middle course), Rio San Jose (also middle course) and others.

> The recent increment in the humidity of the climate apparently was substantiated for an area which exceeds by far that of our country; J. Setzer indicated the possibility of such an increase for Rio Grande do Sul, and it is possible that the Argentinean Mesopotamia and the more humid part of the Pampa experienced the same changes. In contrast, certain counties between the mountain chains and pockets in the west of Cordoba, San Luis and other Argentinean provinces in historic times experienced the effects of a gradual drying action. With respect to the increase of humidity (and the effectiveness of precipitation) the proofs include the slight podzolization of the soil, the desilification of the sandstones of the opaline cement, etc. However, it is likely that during the glacial invasions in the Quaternary an even more humid climate prevailed, each time followed by an increase in dryness. This would explain the presence of terraces or colluvial accumulations in the valleys of some streams, for example near Catalan Chico, Artigas, formed during the rainy phases.

<u>Patterning of the sedimentary cover</u>. The landscape of rounded ridges (and in the more extreme cases of peaks) of the crystalline massif (including the Minas and the Aigua Series) stands opposite the sedimentary formations and the basalt envelope of the northwest also created by fluvial action, with its relatively flat or perfectly flat shapes. The fluvial incision created here systems of ridges and has left as remnants many residual forms, among which we distinguish due to their abundance and their typical aspect the flat ridges (hence the designation of Flat Ridge frequently used in the northern territory), the scarps (primarily that which corresponds to the eastern edge of the basalt ridge) and the widened and flattened promontories (in central Brazil called "trunks") of a sinusoidal edge and with an undecided water shed which as the geological times went by resulted in a line-up of the ridges bearing collective names (for example, Tres Cerros de Cunapiru [Three ridges of Cunapiru]).

On the other hand, the general work of the fluvial patterning offers here some notable local differences, due to the great disparity of the structures and the resistance offered by various materials. Thus the basalt emerges in the landscape, offering sharp contrasts with the sandstone masses of friable cement; on the other hand, the latter, in the present river basin of the Tacuarembo, were dragged in such a way that they permitted the creation of a vast glyptogenic depression thereafter, not exempt from traces of erosion, including secondary riverbeds and "buttes", with the former appearing in the landscape as veritable residual tablelands. The riverbeds, in the more resistant zones, created valleys comparable to rolling ground, a fact which is noted in the so-called Eden Valley of Tacuarembo, cut by an obedient river.

The entire basaltic scarp, located mainly in the departments of Rivera and Tacuarembo was affected by the work of obedient streams (direct or indirect tributaries of the Tacuarembo, a subsequent river). This work has resulted in a constant retrosession of the scarp, in an ever increasing irregularity, and in the appearance of widened and flattened rock promontories which, seen from a distance, simulate flat mountain ranges such as those of the Sierra de Tambores. Scarps also exist in the sandstones, but in general they are smaller and there is no shortage of vertical walls (for example in the Gruta de los Helechos of Tacuarembo) of local importance. At times the very cones of torrential collection, instead of offering their half-basin shape are bordered by vertical walls (one example may be found in the Gruta de los Cuervos, also in Tacuarembo).

The creation of the subsequent depression today drained by part of the Tacuarembo River and the lower course of its principal affluent, the Tacuarembo Chico, uncovered the lower materials corresponding to the Meso- and Eogondwanian and has contributed an enormous amount of sant to the Rio Negro, which was in part deposited in its middle course. Here is where we see today extensive sandstone areas, dispersed by the pampero [a violent wind] and in some cases covered by groupings of yatay palm trees (Porrua and Mujica palms). The deepening of the network,

a phenomenon accompanied perhaps by a local elevation of the crystalline massif (secondary arching "in depth" and an isostatic ascent) caused some tributaries of the Tacuarembo River to incide epigenically on the so-called "crystalline river island" (Cerros Blancos) and in fact to cut it; involved is a phenomenon of super-position perhaps complicated by earlier phenomena due to the arching mentioned earlier. The same deepening of the network caused the Rio Negro to perform its great "percee" [piercing] through the basalt, and to box itself in between the relatively high riverbanks which are so prominent today in it middle course.

> It is possible that the original Rio Negro flowed in the direction of the ocean by way of the present Acegua marshes (where a small stream flows) and those of the Burros glen, a tributary of the Yaguaron River. This sea would occupy the area where today the Laguna Merin is located and its low surrounding lands, which at that time had not yet been shaped. Later on, the isostatic movements and the main bottom arching destroyed this river continuity and the Rio Negro flowed toward the southwest as it does today.

The patterning of the sandstones was a relatively easy task, except in the zones of more or less advanced silicification. The Eogondwana and in part the Meso-Gondwana were flattened without leaving behind a highly irregular terrain, although secondary forms such as scarps, buttes, towers, etc., are quite numerous. The Neogondwan, sloping toward the west, also retrocessed quite rapidly, thus facilitating the creation of the subsequent depression to which we referred previously; if it had been more resistant, it would today present a hill with its corresponding scarp line. This latter fact is appreciably true only in the basalt, located on the Tacurembo sandstones and constituting a prominent "front" of retrogression, corresponding to the phenomena of Post-Cretacean circumdenudation which affected southern Brazil and part of our country. At any rate, the Santa Ana ridge, largely consisting of sediments, Gondwanians (primarily sandstones) has preserved a certain elevation and interposes itself between the depressions of Tacuarembo and Santa Maria in a vast tabular mass of sinusoidal design and accompanied by residual tablelands cut out from it by fluvial action.

Considering the evolution of the scarp of the basalt hill (continued in the Brazilian territory up to the valley of the Ibicuy River) we must point out that the course of the compliant rivers, direct or indirectly tributaries of the Tacuarembo River (Laureles, Lunarejo, Tres Cruces, Tacuarembo Chico, Tambores, etc.) did not only depend on the retrocession or the activity of these streams along the lines or zones of less resistance, but also on the gradual swaying of the basalt mass toward the west (a phenomenon where the deep arching had its effect, in addition to the isostatic effects). Presently, the surface of the basalt hill has a very mild grade, dropping off towards the west (approximately one meter per kilometer); originally, the spillings occurred horizontally (a logical theory, sustained by V. Leinz and other geologists).

> The work of the compliant fluvial streams has separated some ridges from the scarps which still maintain a basalt cap; others have lost it as in certain elevations near the so-called Sierra de la Aurora, Rivera, which in general consists of sandstone ridges. Furthermore a series of widened promontories resulted which appear like flat ridges when observed from the front and from a certain distance (for example, Lunarejo Ridge).

The compliant fluvial network offers a configuration which could be called "polygonal" because it follows the lines of least resistance of the basalt, with the streams running in a zig-zag manner. When the walls along the ravines of a fluvial origin are attacked at the base, they produce major collapses along the diaclases except where the basalt offers a pseudo-laminar or massif structure which protects the remaining mass; if this protection is effective, the lower part is patterned, with the upper part containing pseudo-laminar or massive sizable cornices which produce the locally so-called "galpones" [large sheds](which are characteristic near the settlement of Tambores). The polygonal aspect of the networks only corresponds to the upper river courses; the riverbeds are scalloped when they dominate the horizontal diaclases; when the vertical diaclases are frequent spectacular walls result many times; in some cases the resistance of the rock is sufficient to produce a veritable stone floor at the bottom of the riverbed (which may be observed in the Catalan Chico River, for example).

The structure of the basaltic nappes, followed normally by the vitreous basalt at the base, and in turn by a rock rich in horizontal diaclases which then gives way to a columnar or pseudo-columnar portion, which in turn again becomes pseuo-laminar and finally vacuolar or amygdaloid, affects the aspect of the slope of the ridges, cuchillas and scarps, causing them to become scalloped. Also in the Gondwana sediments of distinct consistency, as in the Mirinaque and River ridges, this scalloping is present although its origin is different.

Very peculiar scarps also occur in the Cretaceous strata which have a certain consistency (silicification, ferrification, etc.); suffice it to recall the Claveles, Acollarados and Mesa de Artigas ridges and the frontal portion of the Gruta del Palacio.

The typical trapp landscape of the basalt regions occurs in Uruguay in a more attenuated way. In the department of Artigas the scalloping caused by the presence of successive spillings may be verified quite clearly. It is curious to note the presence of apparent rounded ridges in the region which a more detailed inspection, upon contemplating the landscape from a certain height shows to be simple terminations of the "trunks" or basalt promontories, which, if viewed from a lower level, simulate ridges. However, in some cases these ridges are real, since the extremities of the promontories were separated from the rest of the mass by fluvial action, at times in various chunks [the case of the Tres Cerros del Catalan).

In some sedimentary formations peculiar phenomena of relief inversion have occurred. This is the case of the broad ridges, of consistent calcites (probably eotertiary) spread out along the Queguay River, but which are also present elsewhere. They were formerly lakes or riverbeds where the calcareous material was deposited, which then silicified in part, resisting the effects of the denudation. While this continued to destroy the surrounding less consistent cover layers, the silicified calcites began forming prominent projections due to their greater resistance to meteorization and erosion. Similar

phenomena of relief inversion can also be observed in other geological formations.

The post-Cretaceous sculpturing of the Uruguayan territory in its sedimentary portion had as a fundamental result the following: the retrogression of the basaltic scarp and the sculpturing of the cuesta surface leading to flattened ridges and scalloped edges (trapp landscape); the partial destruction of the Gondwana sedimentary masses until the subsequent depression of the Tacuarembo River was formed, leading to a relief of flattened ridges, sometimes scalloped edges, and leaving as isolated residuals flat ridges and smaller shapes; the sculpturing and partial destruction of the Cretaceous sedimentary cover layers, some of which today constitute "manchones" (thick patches of vegetation) of small size on the geological map; the considerable flattening of the mild sediments (some of the Eogondwana and others of the Tertiary). In this relief of flat shapes there is no absence of water divides which are known to us under the name of cuchillas. Nevertheless, they differ in general from those which characterize the crystalline massif due to their flat shape, and the frequent presence of marginal scarps. They could be called flat cuchillas or "tableland" cuchillas, although the latter expression, according to R. Maack, appears to be contradictory and is not highly recommended.

The series of cuchillas formed at the expense of the sculpturing of the crystalline massif and of its discordant marginal cover, today forms two principal systems which are connected in Brazil in the zone of Bage: the Haedo System (between the Uruguay River and its affluent the Negro River) and the System of the Cuchilla Grande (between the Negro River and the final portion of the Uruguay River, the River Plate, the Atlantic Ocean and Laguna Merin).

Present systems of cuchillas. The cuchillas are not elevations or lines of relatively isolated elevations, but form a group which is the reflection of the thousand-year action of rivers which had to create their valleys, and there are practically as many cuchillas in a peneplain as there are dual groups or pairs of rivers. On the other hand it is a normal fact in geomorphology and in any relief of extreme maturity there are systems of cuchillas, although in a given region they may not be called that.

Although in our country the systems of cuchillas are somewhat arbitrary, they may be assumed to be real if the Rio Negro is considered as the major limit, in view of the width of its valley which partially resembles a depression. In this case there would be two systems of cuchillas: the one contained between the Uruguay and the Negro Rivers, and the one located between the latter and the territory bounded by the final portion of the Uruguay, River Plate, the Atlantic Ocean, and the Laguna Merin.

In the first sytem the Haedo cuchilla, extended by the Negra cuchilla, constitutes the principal water divide. In effect, it separates the tributaries of the Uruguay River, such as the Cuareim, the Arapey, the Dayman and the Queguay, from those of the Negro River, such as the Tacuarembo, the Salsipuedes stream, and many others. The Santa Ana cuchilla, which borders on Brazil, separates the riverbed of the Tacuarembo from that of the Santa Maria River in Brazil, and in our country it may be considered the principal divide, for which reason we will not speak here of the system of the Santa Ana cuchilla, as we have already done many times.

In the second system, which covers a vastly greater area, the principal divide follows the Cuchilla Grande. If we extend the latter westward, through the Cuchilla Grande del Oeste and finally the San Salvador cuchilla, it would separate the direct tributaries of the Negro River (the Yi River, the Grande and the Cordobes streams, and others) and of the final portion of the Uruguay River (San Salvador River) from those which flow towards the River Plate (Santa Lucia River with its great tributaries, the Rosario and the San Juan streams and others) and those which on the other hand flow toward the Laguna Merin (the Yaguaron and the Tacuari Rivers, etc.). However, the main elevation where the greater peaks of the country are found and where the terrain is mountainous and stony, pertains to the Cuchilla Grande del Este (Eastern); it forms the border between the Laguna Merin basin and that of the Negro River and that which is oriented toward the River Plate estuary. Since the Laguna Merin is connected by way of the San Gonzalo River with the Laguna de los Patos in Brazil, and since the latter is connected with the Atlantic Ocean, the Cuchilla Grande del Este forms a divide between the River Plate basin with respect to the lake basins of Eastern Uruguay and Rio Grande do Sul, whenever we assume the cuchilla to be extended in Brazil for

which reason it is called there Coxilha Grande.

Both systems of cuchillas, the one of Haedo and that of the Cuchilla Grande, are connected in Brazil by way of the Santa Ana cuchilla and form a vast corner where the Negro River begins (Bage zone).

The main secondary cuchillas derived from the Haedo cuchilla, oriented toward the Uruguay River, are those of Belen, of Dayman (or Salto), San Jose (and Medanos), Queguay and Rabon; oriented toward the Negro River, there are those of Navarro (Rio Negro department), Santo Domingo, Once Cerros, and those of Hospital and Caraguata. Some of the cuchillas derived from that of Haedo, oriented toward the Tacuarembo River, such as that of Tres Cruces and Tambores (the latter is also called Sierra) present highly abrupt edges, since they are nothing other than widened promontories of the basalt scarp; the Cuchilla Negra, bordered by the Sierra de la Aurora, also presents abrupt edges (Lunarejo, Masoller).

The Santa Ana cuchilla, a natural continuation to the southeast of the water divide of the Haedo and Negra cuchillas, is typically flattened, and has many branches, among which the cuchillas of Cunapiru, Yaguari, and Hospital and Caraguata already mentioned.

The system of the highly complex Cuchilla Grande, consists of three principal parts: one is located between the Brazilian frontier and the department of Maldonado, which constitutes the mass called by some Central (and others "superior"). From here eastward there are the Cuchilla Mangrullo and the Sierra de los Rios and furthermore the Cuchilla de Cerro Largo, Dionisio, Palomeque and others. The principal branch which points westward is the Cuchilla Grande de Durazno, intercalated between the Negro and the Yi Rivers; furthermore, there are in this direction the branches called Mansavillagra and Santa Lucia.

A second portion enters the department of Maldonado and following the Sierra de Carape terminates in Rocha; it all constitutes a rustic relief where cuchillas and sierras constitute prominent water divides (in Rocha it produces the Carbonera cuchilla, while in Maldonado there are the Sierras de las Animas and de la Ballena, the latter being crossed by the Maldonado).

The third portion which could be called Cuchilla Grande del Oeste (Western) as opposed to the preceding one, which could be called Cuchilla Grande del Este (Eastern) extends westward until it constitutes the border between the departments of Soriano and Colonia under the name of Cuchilla de San Salvador. It produces the tributaries of the Rio Negro such as the Maciel, Marincho, and the Bizcocho, and in the opposite direction (toward the River Plate) the Pintado, Sand Jose (or Guaycuru) and Colonia Rivers.

> There is not always agreement between the sierras and the water divides; thus, for example, the Sierra de la Ballena is cut epigenically by the Maldonado stream and the Sierra de Minas by the Mataojo de la Sierra; furthermore, the sea of stones called "Sierra" Mahoma (San Jose) only partly agrees with the water divide called Cuchilla Mahoma. In turn, the cuchillas always include their corresponding water divide.

[Captions to Photographs Accompanying Source]

Fig. 5. The territory of Uruguay in South America (the insert shows France on the same scale, which represents approximately three times the size of the territory of Uruguay).

Fig. 6. Typical prairie near Lascano (Rocha).

Fig. 7. The peneplane in Cerro Largo (near Melo); rolling fields with pastures and a hill in the valleys. Edge of cuchilla (mountain ridge).

Fig. 8. Schematic map of the principal geological formations of Uruguay and Rio Grande do Sul (the Uruguayan Devonian is marked in black).

Fig. 9. Geomorphological sectors in Uruguay: 1. Valley of the Uruguay River; 2. Basalt Cuesta (hill) (covered in the west partly by Cretaceous sediments); 3. Gondwana Sedimentary Peneplane (including the crystalline river island); 4. Crystalline Peneplane (former massif); 5. River Plate and Atlantic coastal plains (Laguna Merin); 6. Mountain chains in the Crystalline Peneplane.

Fig. 10. Sierra de la Ballena, quartzite monocline crest (Maldonado) oriented from SSW to NNE, consisting of a succession of hogbacks.

Fig. 11. The Chico waterfall of the Uruguay River, constituted by basalt rock.

Fig. 12. Granite outcroppings on the slope of a secondary cuchilla back-to-back with the Guaycuru (which can be seen in the background). Crystalline Peneplane.

Fig. 13. Sculptured edge of a flattened cuchilla (Cuchilla Negra) with a promontory or "trunk" (left). Basaltic cuesta.

Fig. 14. Sierra de Minas, in its quartzite portion, formed by widened ridges, joined at their bases. Foreground: crystalline calcite quarry.

Fig. 15. Cerro de las Animas (Maldonado), highest peak in the country (501 m) seen at a distance from the north.

Fig. 16. Sea of granite stone at the eroded edge of a secondary cuchilla (Sierra Mahoma, San Jose).

Fig. 17. Rounded ridge consisting of old highly-sculptured volcanic materials (Cerro Betete, in the Sierra de las Animas).

Fig. 18. Cerro Batovi (Tacuarembo) consisting of sandstones, flattened on top.

Fig. 19. Stone candle (Puntas del Parao, Treinta y Tres).

Fig. 20. Superposed granite blocks of Mal Abrigo (San Jose), shaped by meteorization.

Fig. 20a. Coastal ravines highly sculptured by fluvial action. (Las Toscas, Canelones).

Fig. 20b. Gramatic blocks rounded an excavated on the base by meteorization (Sierra Mahoma, San Jose).

Fig. 21. Gneiss with dip toward the estuary crossed by dikes of peracidites. pegmatites, etc. Pajas Blancas (Montevideo).

Fig. 22. Quartzite with its cleavage of foliation of Sierra Ballena (Abra de Perdomo, Maldonado).

Fig. 23. "Stone airplane" sculptured in adamelitic granite of the Sierra Mahoma (San Jose).

Fig. 24. Hornblendic schists affected by injections and folded by ptigmatic folds and bends of fragments of ore on the Pajas Blancas coast (Montevideo).

Fig. 25. Trachitic summit (orthophyre) of the Cerro de las Animas (Mirador Nacional, Maldonado).

Fig. 26. Granitic pegmatite mass attacked and sculptured by the estuary waves (Punta Yeguas, Montevideo).

Fig. 27. Rolled corner of porphyry riodacite in Playa las Flores (Maldonado).

Fig. 28. Micro-faults in the striped quartzite of Punta Ballena (Maldonado).

Fig. 29. Porphyry riolite mass of Cerro Arequita, somewhat flattened and with colluvial accumulations on the base (Lavalleja department).

Fig. 30. Brachiopod fossil of the Devonian (Leptocoelia flabellites) corresponding to the lutites of Cordobes ("schists" of Rincon de Alonso).

Fig. 31. Reconstruction of the Gondwanian Mesosaurus (according to J.M. MacGregor) whose remains are found frequently on the Iraty floor (or Mangrullo).

Fig. 32. Remains of a ganoid fossil fish of the Upper Gondwanian sandstones (Tacuarembo).

Fig. 33. Rio Bonito sandstones (or Tres Islas) with crossed stratification (near Melo, Cerro Largo).

Fig. 34. Mud layers of Fray Bentos, constituting ravines near the Uruguay River (south of Paysandu), Tertiary.

Fig. 35. Idealized geological cross-section (somewhat simplified) between the Lower Yaguaron River and the sources of the Arapey River. F shows the basalt "front" and S-A the bottom folds.

Fig. 36. Sandstones of Tacuarembo, forming scarps which lead to the growing roots of trees and bushes in the protected humid zones (Gruta de los Cuervos, Tacuarembo).

Fig. 37. Column-like basalt, near the Cerro del Telegrafo (Rivera).

Fig. 38. Reconstruction of Titanosaurus, a gigantic reptile of the South American Cretaceous fauna (according to A. Cabrera).

Fig. 38a. Structural succession in a series of superposed basalt nappes crowning each corresponding nappe with an abundance of vesicles (and geodes); in this vesicular zone shallow water frequently accumulates.

Fig. 39. The meseta (small tableland) of Artigas, consisting of hard Cretaceous covers in the upper portion (near the Uruguay River, northwest of Paysandu).

Fig. 40. Cuirass of a toothless fossil (glyptodont) and a skeleton of a gravigrade (Lestodon) of the Pampean Formation, preserved in the Museum of Colonia.

Fig. 41. Columns (elephant paws) of Gruta del Palacio (Department of Flores). Photo by K. Walther.

Fig. 42. Geological profile of the Punta Gorda (Colonia) steep cliff where it is assumed that the Uruguay River and the River Plate join (formations of the second half of the Tertiary).

Fig. 43. Agates and "bowls" of Calcedonia, separated by the meteorization of the basalt and which form agglomerates in the Artigua streams (A. Catalan Chico).

Fig. 44. Pampa mud covers (with calcite concretions) sculptured by fluvial erosion (Montevideo).

Fig. 44a. Tertiary covers (probably Pliocenic) topped by pampa mud in the River Plate coastlands of Colonia, near this city, bordered by landslide residue.

Fig. 45. Sample of vacuolar basalt, partially amygdaloid (full of calcite and other minerals) near Paso de Porrua, on the Rio Negro.

Fig. 46. Sand bank semifixed by Panicum racemosum, near a live sand bank (vicinity of Punta Piedras de Afilar, Canelones).

Fig. 47. Yardangs created by eolic deflaction in sand slightly cemented by iron oxides (near Paso Porrua, on the Rio Negro.

Fig. 48. Block diagram showing the relationships between the crystalline massif Cr and the Gondwanian sediments G topped by the basalt layer F (and the Recent sediments L). DS and T show the subsequent depression; 1 and 2 show the anticlines of the basic fold; Ch shows the flat ridges separated by erosion.

Fig. 49. Central portion of the Sierra de Minas, with granite and porphyry ridges and with cones of torrential collection, created in resistant rock. In the foreground a dale (pass through the Sierra).

Fig. 50. Monocline quartzite crest of the Sierra Ballena,1 bordering on vegetation of mountain chirca [euphorbia tree] and further down common chirca and field with carqueja.

Fig. 51. Sugarloaf Peak, some 400 m high, consisting of sienites and granite (Maldonado) next to Piriapolis.

Fig. 52. Stone hats created by the reduction of the base portion, more humid and shady, of the granite materials of the Sierra Mahoma.

Fig. 53. Initiation of the base excavation process by chemical action enhanced by the persistence of humidity in the shade on an adamelite block of the Sierra Mahoma.

Fig. 54. Stone caparison corresponding to the advanced phase of the process started earlier on an adamelite block of the Sierra Mahoma.

Fig. 55. Formation of cuchillas (mountain ridges).
D -- Main cuchilla, formed by the first order streams.
In SS' the secondary cuchillas emerge formed by the second order streams.

Fig. 56. Gneiss and gneissoid granite, affected by intense dynamometamorphosis, produced at the outcropping of the stone sea called "sierras" of Mal Abrigo.

Fig. 57. Dale of Perdomo, a pass of epigenic origin, which provides communications through the resistent Sierra Ballena (quartzitic). In the foreground brambles of mountain chircas and rosemary.

Fig. 58. Gradual passage from a flat cuchilla, consisting of Gondwanian sediments to a succession of flat mountain ridges.

Fig. 59. Tacuarembo sandstone towers, rising as evidence of erosion (Gruta de los Helechos, Tacuarembo).

Fig. 60. Lined-up tablelands (flat mountain ridges) resulting from the destruction of a flat cuchilla, constituting evidence of erosion in the glyptogenic depression of the Tacuarembo River (Tres Cerros de Cunapiru, Rivera).

Fig. 61. The largest of the Tres Cerros de Cunapiru, residual tableland, Gondwanian tabular masses partially destroyed (Rivera). Foreground, well-developed vegetation of common chirca.

Fig. 62. Trunks (promontories) of the wavy scarp of the Cuchilla Negra (edge of the basaltic tabular mass) and "butte" ridge separated from them by glyptogenic action (Cerro Buen Retiro, Rivera).

Fig. 63. The Gruta del Palacio, a curious formation created by the work of dissolution and ablation of the water, in the reddish sandstones of Palacio (Department of Flores).

Fig. 63a. Hypsometric map of Uruguay.

Fig. 64. Flat cuchillas of sediments topped by basalt (Tacuarembo).

Fig. 65. Sedimentary slightly wavy plain covered with butia palm trees (Rocha).

Fig. 66. Trunk or basaltic promontory derived from an irregularity in the Cuchilla Negra (Cerro Lunarejo, Rivera).

Fig. 67. Cerro Mirinaque (Rivera) of scallpped hillsides.

Fig. 68. Recent sediments located east of the crystalline massif which show the effect of a "resumption of erosion" (Rocha).

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